UPDATE IN ANAESTHESIA

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EDITORIAL

Welcome to Update in Anaesthesia Number 15. We hope that you find this issue of interest. Feedback is always welcomed, particularly suggestions for topics and contributions. Please contact the editor before preparing articles to check suitability and to receive guidelines on writing for Update. All articles contributed to Update are peer reviewed before publication.

Following requests from readers we are producing a bound set of reprints of Update in Anaesthesia 6 - 12. These will be available in 2003 from Teaching Aids at Low Cost (talc@talcuk.org). The price is expected to be around £8 - £10 including postage. Electronic copies of the entire collection of Update in Anaesthesa are available free of charge in the form of a CD Rom. This CD also contains the Primary Trauma Care manual and other useful reference material. Contact the editor (iain.wilson5@virgin.net) for details.

In this edition we have reviewed both a handbook of anaesthesia, and a CD ROM which has been produced by e-TALC, a new electronic based development of Teaching Aids at Low Cost. We would like to increase the number of reviews we publish and would be delighted to receive books and other products which may be of interest to readers. We shall arrange a reviewer and publication to promote suitable material.

Update is available on the internet in French, Russian and we hope that the Spanish version will become available in 2003. The web addresses are printed under 'Contacts' on this page.

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Dr Frank Walters.

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RELIEF FROM CHRONIC PAIN WHEN RESOURCES ARE LIMITED.

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The Indian health care scene has a curious mix of paradoxes. Advances in Cardiovascular surgery or high-tech investigative facilities in India are on par with any advanced country at least in some cities. But across the road from a high tech hospital, it will be easy to find hundreds denied of primary health care. Pain relief is a case in point. At least a million people in India suffer unrelieved cancer pain. The number of people suffering other chronic pain conditions is anyone's guess. India is not alone. The situation is common to most of the developing world.

For any medical advance to occur, the initiative has to come from either the professionals or from the executive. Neither happens in the field of pain. Unlike high-tech medicine, pain treatment lacks glamour. So it does not attract the professional. The executive does not consider this a priority. Control of infectious diseases is a priority item; pain control is not.

But it should be. The extent of suffering in the community is enormous. And unnecessary. Most of chronic pain can be effectively treated by simple measures. And it is up to us professionals to point this out to the administrators and to generate some interest.

For this, the first requirement is that pain relief centres should be able to demonstrate efficacy and cost effectiveness. Unfortunately, even interested professionals or institutions often lack a sense of direction. Many professionals attempt to treat pain single-handedly, employing those treatment modalities with which they are most familiar and in which they are most skilled. The anaesthetist uses nerve blocks, the acupuncturist attempts to treat every pain with acupuncture and the physiatrist relies on physical measures alone. This approach is doomed to fail.

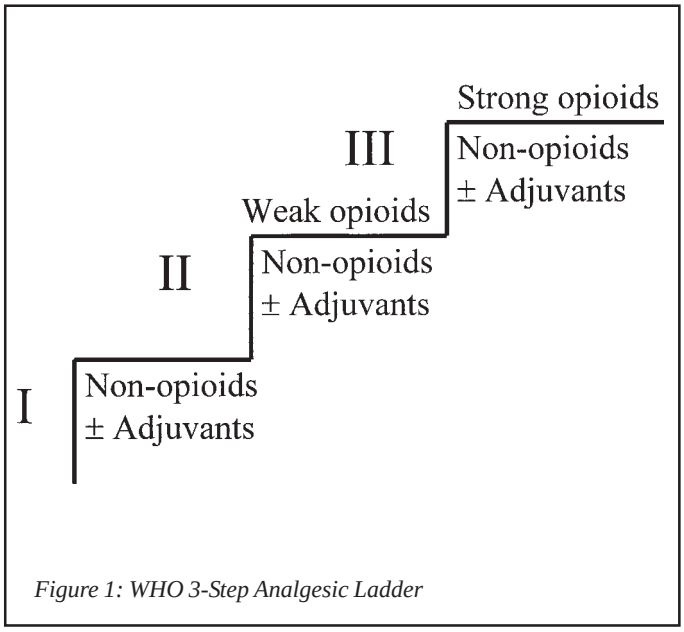

Figure 1: WHO 3-Step Analgesic Ladder

The hardest part in pain treatment is that it requires multi-disciplinary approach. In an ideal world, every specialist's opinion should be pooled with those of the nurse and the psychologist, and the perfect treatment decided on, of course with the involvement of the patient and the relatives. But this theoretical ideal can never be reached. Several professionals sitting around one table to look after a patient is a Utopian dream which can never be practiced, considering how busy professionals are.

The answer is for the pain therapist to understand the importance of the multidisciplinary approach. He must be prepared to take on the role of the general practitioner and to look at the problem from the patient's point of view. He will have to assess the pain and the degree of emotional involvement in the pain experience and then consider various therapeutic options. And when necessary seek the help of other specialists.

Management of Pain

Assessment of pain need be no more difficult in the developing world than in more advanced countries, because (with some exceptions) evaluation is clinical. What is needed is only the expertise - the ability to distinguish between a nociceptive pain and a neuropathic pain, for example. It is also important to remember the concept of total pain: pain is not just a sensation. It is "*a sensory and emotional experience*"[1]. Physical pain will inevitably be modified by social, emotional and spiritual factors. Therefore attempts to treat chronic pain only as a physical entity are bound to be ineffective. Every pain therapist will need to learn the fundamentals of counseling and communication skills. And the patient must be believed about the pain. "*Pain is what the patient says, hurts*"[2].

The World Health Organisation (WHO) analgesic ladder

The World Health Organisation (WHO) Three-step Analgesic Ladder[3] (Figure 1) has revolutionized treatment of cancer pain all over the world. It involves the use of oral drug therapy by the clock, depending on the duration of action of the drug. In step I, non-opioids like paracetamol or NSAIDs are used. When they are inadequate to control pain, weak opioids like codeine or dextro-propoxyphene are added. If this fails to control the pain, the weak opioid is stopped and a strong opioid like morphine is substituted. The most important principle in practicing the ladder are:

- Give drugs **by mouth** whenever possible. Injections are impractical in the long term and add to discomfort.
- Allergic manifestations, including bronchospasm, which is uncommon with oral therapy.

As these drugs are usually effective only if given round the clock, the following recommendations for the frequency of administration may be helpful.

- Give the drugs **by the clock** depending on the duration of action of each individual drug.

Step 1

For a mild pain of the obvious nociceptive nature, it is amazing how much benefit a simple drug like paracetamol can give if used by the clock - say, 4-6hourly. No other analgesic has less of side effects; and it is quite safe to use it in the long term even in doses as high as 4-6g/day. Even if it is not enough to give a reasonable degree of pain relief, it can reduce the dose of more potent drugs.

Most non-steroidal anti-inflammatory drugs (NSAIDs) are used in the long term by mouth to treat cancer pain. They can be used safely if we remember the most important side-effects namely,

- Gastritis (If this happens, a concurrent H_2 blocker may be needed).
- Platelet dysfunction
- Possibility of renal failure in the patient who is predisposed to it.

Drug	Frequency in hours
Aspirin	4-6 hourly
Ibuprofen	6-8 hourly
Diclofenac	8-12 hourly
Ketorolac	6-8 hourly
Some COX-2 selective NSAIDs are relatively inexpensive in India	
Meloxicam	24 hourly
Rofecoxib	24 hourly

Step II

If step I by itself is inadequate to control the pain, step II involves the addition of a weak opioid. The commonly available drugs in India, the recommended dose and the required frequency of administration are:

Drug	Frequency in hours
Codeine 30 - 60mg	4 hourly
Dextropropoxyphene 65mg (This is usually available only in combination with paracetamol).	6-8 hourly
Tramadol 50-100mg	6-8 hourly
Buprenorphine (0.2-0.4mg sublingual) (Many would include buprenorphine among strong opioids)	6-8 hourly

Dextropropoxyphene is the least expensive among the lot. Tramadol is more potent; but expensive. Pentazocine is available for oral use, but is not recommended because it causes dysphoria and has too short a duration of action[4]. Weak opioids have a special place in our country because of limited availability of oral morphine. But unfortunately they all seem to have a ceiling effect. This means that their dose can be increased only up to a point. This limits their use in severe pain.

Step III

When step II drugs are inadequate to treat pain, step III involves continuing the step I drugs, stopping the weak opioids and adding a strong opioid.

Oral morphine is the mainstay of treatment of severe cancer pain. Contrary to popular belief, oral morphine (when used for opioid-sensitive pain, with dose titrated to the degree of pain relief) **does not cause addiction or respiratory depression**[4]. An overdose causes side effects like drowsiness, delirium and myoclonus, which serve as warning signs.

The usual starting dose is 5-10mg. As required, the dose is increased by 50% every 1-2 days, till the desired effect is reached. The following are the common side effects:

- Constipation can be troublesome, and almost all patients on opioids require laxatives. The choice in this case would be a stimulant laxative like bisacodyl or senna. It can be usefully combined with a softener/lubricant like docusate or liquid paraffin.
- Up to one third of patients get vomiting in the first few days of therapy and require anti-emetics.
- Up to one third of patients feel tired especially in the first few days of therapy. A few may also have anorexia.
- Urinary hesitancy is a relatively rare side effect.
- A few may have pruritus. This usually disappears with a few days of anithistaminics.

Bypassing steps I and II

Pain clinics in India being few and far between, we often see patients in long-standing excruciating pain. The concept of WHO analgesic ladder, obviously, needs to be modified in such pain emergencies. One possibility is to use titrated intravenous bolus doses of 1.5mg of morphine every ten minutes till eventually the patient either gets pain relief or becomes drowsy[5]. If the patient gets drowsy while still in pain, it indicates that the patient has at least some opioid-insensitive pain. An alternative in cancer pain emergencies is to start the patient on 10mg oral morphine every hour till pain relief is achieved[6]. The point to be emphasised here is that in severe cancer pain, there is a case for bypassing the first two steps of the ladder.

Availability of oral morphine

India has the paradoxical situation of supplying the rest of the world with opium for medical purposes, while our own patients are denied pain relief. Stringent and unrealistic narcotic regulations are responsible for this situation. Efforts are under way to simplify narcotic regulations. Seven states in India now

have simplified narcotic regulations that make availability of oral morphine easier[7]. A complicated licensing system is necessary in the other states.

Adjuvant Analgesics in Opioid-Resistant Pain

Adjuvant analgesics are drugs that have no analgesic action per se, but in a particular context confer pain relief. Not all pains respond to opioids. Some of them respond only partially. Administration of morphine to such a patient will make him more miserable by causing drowsiness, tiredness, delirium or myoclonus. The following types of pains are examples of relatively opioid-resistant pains.

- **Muscular pains**. (Should be treated by muscle relaxants and injection of myofascial trigger points in some cases).
- **Colicky pain**. (This responds to antispasmodics like hyoscine butylbromide or dicyclomine).
- **Bone pain**. (Here, opioids need to be combined with NSAIDs, and in some cases, with corticosteroids).
- **Pain in constipation**.
- **Neuropathic pain**.

General Principles of Management of Neuropathic Pain

The mainstay in the treatment of neuropathic pain is the use of two groups of drugs, **anticonvulsants and antidepressants**[8]. Either could be the first-line drug. Antidepressants are better tolerated and for many centers, they form the first line drug. When one alone fails, combinations of the two might work. Usual doses of these drugs are:

Anticonvulsants	
Carbamazepine	200 - 400 mg 8 hourly
Phenytoin	200 - 400 mg daily
Sodium valproate	Up to 1200 mg nocte.
Tricyclic antidepressants	
Amitryptilene	25 - 75 mg at bed-time
Doxepin	25 - 75 mg at bed-time

As they all cause significant side effects, the starting dose should be low, and the dose should be increased gradually. And side effects should be looked for and treated.

Anticonvulsants act by membrane stabilization. It is possible that sodium valproate also works by GABA enhancement[4]. Tricyclic antidepressants act on the descending inhibitory pathways by preventing re-uptake of serotonin and norepinephrine and thus increasing the concentration of these inhibitory neurotransmitters at the synapses.

When these two first-line drugs are inadequate to control neuropathic pain, there are several other options. One is the oral administration of local anaesthetic agents like **mexiletine**. An intravenous dose of **lignocaine**, 1mg/Kg can be used as a therapeutic trial. If it succeeds in achieving analgesia for more than 20 minutes (a short-lived analgesia could be because of placebo effect) then the patient can be started on oral mexiletine on a regular basis[9].

Ketamine hydrochloride, an anaesthetic agent that acts on the NMDA receptor also has been successfully used orally in the relief of intractable neuropathic pain[10]. It can be started in a dose of 0.5mg/Kg six-hourly, and gradually increased. However, there can be significant side effects like delirium and hallucinations. **Amantidine**, an anti-parkinsonism drug, also has been shown to cause NMDA -antagonism and has been seen to be of help in nerve injury type of pain. It is used in doses of 50 - 100mg daily[11].

Corticosteroids are of particular value in nerve compression pain and in pain of elevated intracranial tension.They may be administered systemically, but when feasible, local drug delivery (such as epidural) has advantages. Dexamethasone is the preferred agent for systemic administration and triamcinolone for epidural injection.

Some local measures can be of help. When there is significant cutaneous hyperalgesia, a topical agent like **capsaicin** may help. When there is accessible normal nerve proximal to the lesion, **Transcutaneous Electrical Nerve Stimulation (TENS)** can be helpful. **Repeated stellate ganglion local anaesthetic blocks** are recommended for complex regional pain syndrome (CRPS) of the upper limb.

When oral drug therapy fails, central measures **like continuous epidural analgesia or neurolytic procedures** may be indicated. Coeliac plexus blockade in upper abdominal malignancy is an example. These have particular relevance when the patient comes from too far away for review and for titration of drug doses. When facilities like image intensifier are unavailable, other practical solutions may have to be sought, like thoracic epidural alcohol injection for pain of thoracic and upper abdominal malignancy[12].

General Principles of Pain Management

The following general principles may be useful for people who venture to the field of pain relief.

- Identification of the type of pain is key to successful treatment of pain. Therapeutic modalities to be followed in neuropathic pain, say, are significantly different from those needed in bone pain.
- Remember that any pain, if long-standing, can become centrally established. Neural tissue can develop anatomical and even genetic alterations. Once a pain is centrally established, peripheral attempts at treating them (like peripheral nerve blocks) are bound to be ineffective
- Somatisation: When negative feelings like fear or anger are brought out as physical symptoms like pain, it is called "somatisation". It is common for doctors to feel irritated about it. But we should remember that somatisation is not the patient's fault. There may be emotional reasons behind the pain. It is up to the doctor to identify it and to deal with it.
- While a particular intervention like a nerve block may have its relevance in a particular case, drug therapy is usually the ideal basic therapeutic modality in a large number of patients.

- The obviously perfect form of therapy (from the physician's point of view) may be totally unsuitable if it is unaffordable to the patient. The patient's financial status must be taken into consideration when planning treatment.

Development of a Pain Relief Service

Any attempt at solving the pain problem in a poor country has to take into account the enormity of numbers and should be realistic. We find that about 80% of patients approaching a pain clinic have cancer pain[13]. Two parallel services have developed in the West - the pain clinics run mostly by anaesthetists and the 'hospice' or palliative care service. Neither is well established in India or in most of developing world. Much of the needs are common in both services, and perhaps an integration of both services is the most practical solution for us.

When we developed a palliative care unit in Calicut[14] we based it on the following principles.

- **The patients' needs should come first**. This may sound obvious; but does not often get practiced. We need to remind ourselves that our efforts can succeed only if the management is based on what the patient needs for improved quality of life.

- **The care delivery system should be realistic**. It has to suit the local cultural and economic background

- **Doctors need to establish a partnership in care with the family**. The strength in India is in the strong family structure. Empowering relatives to care for the patient can achieve a lot.

- **A partnership in care also needs to be established with the patient**. The average villager is quite capable of making brave and intelligent decisions regarding treatment options. Formal education and intelligence are not synonymous. Doctors have no right to force decisions on the patient.

- **We have to make use of existing resources**. India has the advantage of a network of primary, secondary and tertiary health care centers. These have their advantages and their drawbacks. We need to use whatever the existing machinery has to offer. If we don't, we will end up spending too much.

- **Deficiencies in existing facilities need to be supplemented by NGOs**. We must find ways to supplement all shortcomings in the available machinery. If non-Government organizations (NGOs) can work with the Government machinery, it could prove to be of benefit to the patient.

- **Willing volunteers can be the backbone of the facility**. There are numerous individuals who are kind hearted and are willing to help. This strong work force only needs to be organized and channeled properly.

The Calicut Experience

In Calicut, a small city in the South Indian state of Kerala, we have developed an organisation that could be represented with the patient at the apex, the relatives and the volunteers next to them and the medical system supporting them. The medical system in this case involves both the Government machinery and an NGO[14]. A clinic works in the Government Medical College Hospital, supported by The Pain and Palliative Care Society, a registered charitable organisation with its headquarters at Calicut. It finds and trains volunteers and provides essential staff, equipment, and drugs wherever the Government machinery falls short.

The system, over the last eight years, has grown to reach an average of 2000 patients a year in the parent clinic at Calicut. Daily patient attendance now averages 60 and the clinic sees an average of 100 - 130 new patients a month. We work with local doctors and NGOs to establish peripheral centers in neighboring districts. 27 such clinics are operative now in the various parts of Kerala. In some of them there are also home visit programmes to look after those who are too sick to travel to a clinic[15]. We now estimate that 15% of the needy in Kerala have access to pain relief and palliative care.

While it is true that a lot has been achieved in eight years, there are still a million more in India in need of pain relief. To reach out and to ease them, we do not need a lot of expensive gadgetry or sophistication. Morphine manufactured in India out of poppy already grown in India, a few other not-too-expensive drugs, and the realization among administrators and professionals that freedom from pain is a human right, are all that are needed.

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This article on Chronic Pain Management in Difficult Situations was commissioned by the WFSA Committee on Pain Relief for publication in Update in Anaesthesia. Dr Rajagopal is part of a team that started with minimal resources and built an excellent pain and palliative care centre, which is now recognised by WHO as a role model for developing countries and utilised by WHO as their training centre.

LETTER TO THE EDITOR

Dear Sir,

Why do my patients shiver after anaesthesia and is there anything that I can do for them?

A reader from Zimbabwe

Comment by Dr William English

Post-operative shivering, causes, prevention and treatment.

Shivering is a frequent occurrence in the post-operative period. The primary cause of post-anaesthetic shivering (PAS) is per-operative hypothermia secondary to anaesthetic induced inhibition of thermoregulation. This causes both cutaneous vasodilation and reduction in the thresholds for activation of vasoconstriction and shivering. In turn this results in redistribution of body heat from core to periphery with subsequent rapid hypothermia during anaesthesia. Shivering itself however may be associated with cutaneous vasodilatation, particularly in the context of post-operative pain.

Apart from causing discomfort and exacerbating post-operative pain, PAS has been shown to increase oxygen consumption, catecholamine release, cardiac output, heart rate, blood pressure and intra-ocular pressure.[1] It also commonly interferes with routine monitoring.

Studies have identified a host of different precipitating factors including male sex, duration of anaesthetic, spontaneous breathing techniques, the use of volatile agents and anticholinergic pre-medications.[1]

Whilst not all patients who shiver are hypothermic prevention of PAS mainly entails preventing per-operative heat loss. This can be achieved by a number of different techniques such as increasing the ambient temperature in theatre, using conventional or forced warm air blankets and using warmed intravenous fluids.

Whilst these methods may obviously continue to be employed in the recovery room, pharmacological agents are the most popular mode of treatment of PAS as well as having a prophylactic role.

The neurotransmitter pathways involved in the mechanism of PAS are complex and still poorly understood. There is evidence that opioid, alpha 2 adrenergic, serotenergic and anticholinergic systems are probably involved by virtue of the fact that drugs acting on these systems may be utilised in the treatment of the condition.

Some of the drugs validated in clinical trials in both the treatment and prophylaxis of PAS are shown in the table below together with the approximate doses. [2, 3, 4, 5]

Drug	Suggested Dose and Route	Role
Pethidine	0.35 mg/kg may repeat x 4 at 5 min. intervals iv	Treatment
Clonidine	0.15 mg iv	Treatment
Tramadol	1mg/kg iv	Treatment or Prophylaxis
Ondansetron	8mg iv	Prophylaxis

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GOING ELECTRONIC?

The Health and Development Resources CD-ROM - Teaching aids at Low Cost (TALC). 1st Edition, June 2002
Review by Tim Hughes, Consultant Anaesthetist, Doncaster, UK

TALC is a UK based charity that has provided healthcare related educational material to developing countries since 1965. This CD-ROM is an early result of a project supported by the UK Government's Department for International Development. Their objectives are to:

- produce easy to use, interactive and copyright-free CD-ROMs
- provide a low cost method for distributing health care information and sharing ideas between developed and developing countries.
- educate users about web technology in anticipation of increasing future Internet access possibilities.

Ever since getting tangled up in a 'Hula-Hoop' as a child, I have been deeply suspicious of colourful round things with holes in the middle; particularly when they are claimed to be easy to use! I am therefore perhaps the appropriate type of character to explore and review this CD-ROM. A natural or knowledgeable computer user I am not; tending to be somewhat of a dinosaur when it comes to the idea of replacing printed paper with shiny discs, despite our increasing professional reliance on the electronic medium in recent years. Fair enough; there is an inevitable reduction in bulk, storage management effort, and distribution costs. But this is balanced by the need for a working "white box" (computer plus CD-ROM drive) with appropriate software, a predictable source of electrical power and, if dependent on the Internet, a reliable phone link. Such resources are still not readily available in many countries.

Starting up is a straightforward matter of following some clear instructions, which include the opportunity to download Acrobat Reader to take advantage of both HTML and PDF formats. The CD is organised into contributor 'sections' that are linked through an integral ISYS search engine. This feature is simple to download and use, as long as you are working with a Windows (95 or later) operating system. Some of the 14 contributors in this edition have taken advantage of the electronic format potential better than others, and I can't understand why only the World Anaesthesia section appears to offer downloadable web browser software. Future editions might make this available with initial loading of the disc.

Even I have to confess that "browsing" this electronic resource has been fun; a feeling that doesn't always come immediately to the surface when one describes handling a medical journal or textbook! The contents include a wide-ranging selection of healthcare information but inevitably I began by navigating my way through some anaesthetic topics.

A simple search for material on ***morphine*** (which I should know well) and ***ketamine*** (with which I have significantly less personal experience) sent me on a journey through reviews from the complete collection of ***Update in Anaesthesia***; via a ***Reference Material*** collection of tutorials and international journal review articles developed by the WSFA and World Anaesthesia; to editions of the ***Uganda Continuing Medical Education Newsletter***; visiting evidenced based review abstracts from the ***Cochrane Library*** on the way; and finally surfacing inside the ***Primary Trauma Care Manual***. As the length of the preceding sentence indicates, this was a journey through a veritable maze of information that left me yearning for a slightly more selective searching tool.

Exploring more general health issues such as current thoughts on the prevention of malaria or HIV in the developing world brought further components into play. Notable amongst these is a full copy of UNICEF's "Facts of Life" document on child health, and the *Community Eye Health* teaching material which includes an interesting slide collection.

If I had chosen to take advantage of the many offered Internet links and wandered off into the 'electronic ether', then I would have found many familiar and not so familiar additional delights. In fact some contributors currently rely perhaps too heavily on their web links. However, those users without the essential phone lines for such indulgences can console themselves with the self-sufficiency that many sections of this package represent.

While I found this resource generally well organised, contributors were variable in the provision of introductory guidance on how to get the best from their 'sections'; with World Anaesthesia coming out best in this regard. This first issue is essentially an English language based system, with the exception of the *Primary Trauma Care* 'section' which offers Chinese, French and Indonesian language options. Fortunately I couldn't get the Chinese version to run for me!

Despite the obvious time and effort that has gone into it so far, the project is clearly in its infancy with TALC looking for more partners who will contribute to and help develop the content. I can't help but feel that, for cost advantage if for no other reason, those in developing countries will reconcile themselves to such electronic alternatives to the printed word faster than those in "developed" areas. No doubt, TALC are more than delighted to receive constructive advice on future improvements through the feedback mechanism offered in the introductory pages of all sections. With the resulting continuing development, the stated objectives are more than likely to be achieved; with this CD-ROM becoming a little treasure-trove for health professionals throughout the world.

Get one of your own and try it out. You can't have mine; it's going to a friend in Tanzania when I've made a copy for myself!

Copies can be obtained from:
Unit 13, Oxford Enterprise Centre, Standingford House
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PHARMACOLOGY 2 - PHARMACOKINETICS

Dr Lauren Barker, Specialist Registrar, Bristol Children's Hospital, Bristol, United Kingdom and Dr Lesley Bromley, Senior Lecturer in Anaesthesia, University College London UK.

Pharmacokinetics is the study of the way the body deals with any drugs that are given to it. Simply put "what the body does to a drug". In pharmacokinetics we study the processes of absorption, distribution, and elimination, either by metabolism or excretion, of drugs. Detailed pharmacokinetic studies quantify these events and their time course. The principles underlying pharmacokinetics help in the understanding of the methods of drug delivery used in anaesthesia, and the use of such techniques as total intravenous anaesthesia.

In this article we shall deal with the processes of pharmacokinetics in the three major areas:-

1. Absorption
2. Distribution
3. Elimination - Metabolism
   - Excretion

ABSORPTION

Most drugs do not have their site of action in the GI tract, or the plasma. They therefore need to cross cell membranes to reach their site of action. There are 3 ways in which drugs can cross lipid membranes:-

a) Simple diffusion.

Drug molecules move from a high to a low concentration. This is a passive process and no energy is required for it.

b) Non-ionic diffusion.

Most drugs are chemically weak acids or weak bases. This means that when dissolved in water they will either give us a hydrogen ion and become ionised (acids) or accept a hydrogen ion from the water and become ionised (bases). The ionised form has an electric charge, and in this form it cannot cross a lipid membrane.

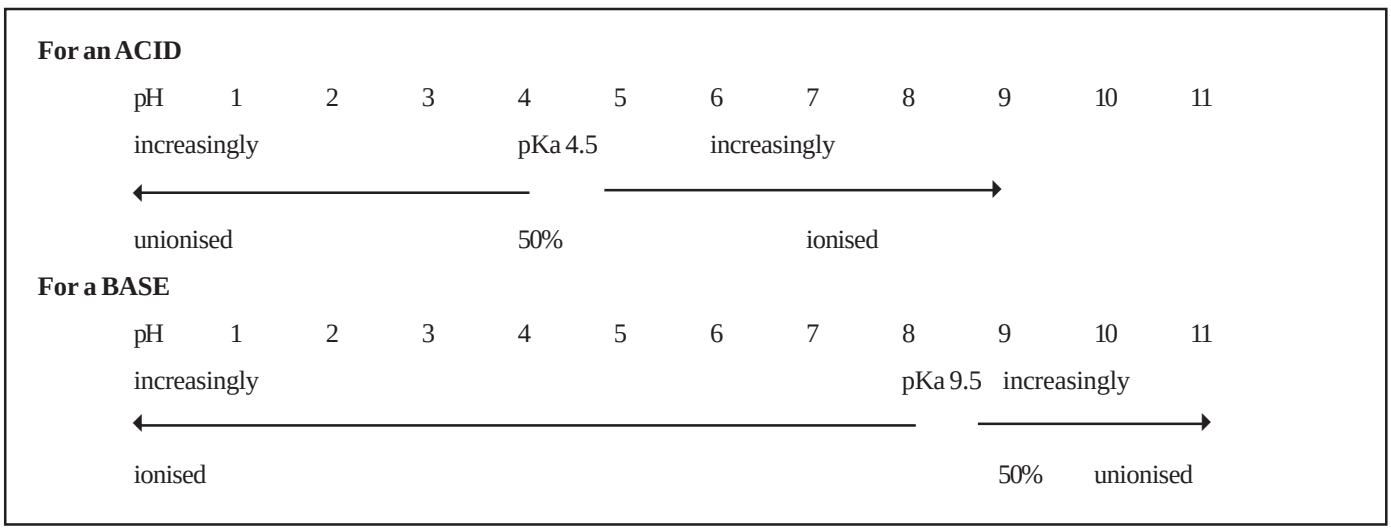
When in solution, the ionised form of the drug is present in equilibrium with the unionised form. How much of the drug changes to the ionised form will depend on two factors. The first is a characteristic of the drug and is called the pKa. It is a constant. The second is the pH of the solution. (See also Acid Base Balance, *Update in Anaesthesia* 2001:13;52). This is obvious if thought about for a moment. The pH of the solution indicates the hydrogen ion concentration, and so it will influence the rate of dissociation of both weak acids and weak bases. Weak **acids** dissociate, becoming **ionised**, in an **alkaline** environment (i.e. give up their hydrogen ions where there are relatively few, and weak **bases** become **ionised** in an **acid** environment (ie gain hydrogen ions where they are relatively plentiful).

The pKa of a drug is related to the equilibrium that the drug has with its ionised form, it also happens to be the pH of the solution at which 50% of the drug will be ionised and 50% will be unionised. When the pH is the same as pKa the ratio of ionised to unionised drug will be 50:50. i.e. the pKa is the pH at which the drug is 50% ionised.

This is important for absorption because, as we have said, only the unionised form of the drug is lipid soluble and can cross cell membranes. The ionised form cannot cross the membrane easily.

Examples of acidic drugs include phenytoin, thiopentone, aspirin (salicylate), and penicillins. Basic drugs include diazepam, local anaesthetic drugs, non-depolarising neuromuscular blocking drugs, morphine and pethidine.

An example where this is relevant is the increased dissociation or ionisation of local anaesthetic agents (a basic drug) in infected tissues that tend to be acidic. There is less in the unionised form, required to cross the nerve cell membrane. This explains why lignocaine, when infiltrated into infected tissues has a poor effect. See Table one.



Some pKa's of common drugs

		pKa's	
STRONG		0	WEAK
		caffeine	
		1	
		2	
	benzypenicillin		
A		3	B
		diazepam	
C		4	A
	aspirin	chordiazepoxide	
I		5	S
	dicoumarol		
D		6 codeine	E
	sulphadiazine		
S		7	
	phenobarbitone		
		8 lignocaine	
	phenytoin	9 chlorpromazine	
		atropine	
		10	
		11	
WEAK			STRONG

Table 1

c) Carrier transport

Proteins within the cell membrane may act as carriers for the drug. These carriers are usually specific for the drug; they usually carry the drug in one direction only across the membrane and may be inhibited or affected by other drugs. Ionised forms of the drug may be able to cross the cell by carrier transport. For example the penicillins are actively excreted in the kidney by this type of transport mechanism. Probenecid is another drug, which uses the same transport mechanism but is preferentially excreted over penicillin. It has been used to prolong the duration of action of penicillins, by slowing excretion.

There are 2 types of carrier transport:

- facilitated diffusion in which drug molecules move passively across the membrane from a high to a low concentration, attached to a carrier. No energy is required for this process.

- active transport in which, on the other hand, drug molecules can be transferred against a concentration gradient (from a high to a low concentration). This process requires energy (ATP).

Routes of Absorption

Oral. The oral route is pleasant and convenient and is therefore widely used. Where and how the drug will be absorbed from the gastro-intestinal tract depends on a number of factors. The formulation, tablet or capsule form, its sensitivity to enzymatic attack, gut motility and how fat-soluble the drug is will all influence absorption. Gut pH plays an important role as it will affect how much of the drug is in the unionised form and therefore how much of the drug is fat-soluble, and will be absorbed. The stomach contents are very acidic with a low pH. Therefore, acidic drugs are more unionised and tend to be absorbed there. In contrast the small bowel is more alkaline (a higher pH) which will favour the absorption of basic drugs. The example most frequently quoted to illustrate this is aspirin, which has a pKa of 4.4 and is therefore relatively unionised in the gastric fluid that has a pH of approximately 1. This favours absorption of aspirin in the stomach. When aspirin passes into the small intestine, the equilibrium moves towards more ionised aspirin molecules, theoretically favouring less absorption. In actual fact the majority of aspirin is absorbed in the small intestine, because there is a very much greater surface area available for the absorption to take place. This shows how many factors contribute to the final process of absorption.

All drugs that cross the intestinal mucosa, enter the portal circulation, and pass through the liver before entering the systemic circulation. Most drugs will only reach their site of action from the systemic circulation. Some drugs, however, will be significantly broken down (metabolised) by the gut wall or by the liver before they reach the systemic circulation. This means that they will have a much lower concentration in the systemic circulation and at their site of action than might be expected from the dose given. This is called the first pass effect. It only affects drugs given orally and can be avoided by giving drugs by intravenous, intramuscular, subcutaneous or sublingual (under the tongue) routes. This is because the blood supply from these areas does not pass though the liver via the portal circulation, but drains directly into the systemic circulation. Examples of drugs with high first pass metabolism are propranolol and lignocaine which undergo liver metabolism, and morphine which is metabolised both in the gut mucosa and in the liver. When the oral dose of a drug is much larger than the intravenous dose it indicates that the drug has a high first pass metabolism.

The bioavailability of a drug by any route is the ratio of the amount of drug reaching the circulation, to the amount present if the drug had been given intravenously. So a drug might have an oral bioavailability, and an intramuscular bioavailability which is different. It is expressed a percentage so a drug given intravenously have a bioavailability of 100%. We can express this in a mathematical way:

$$\textbf{Oral bioavailability} = \frac{\text{Amount of drug in the circulation after an oral dose} \times 100}{\text{Amount of drug in the circulation after an IV dose}}$$

Considering some other routes:

Intravenous. The drug enters the systemic circulation directly and bypasses the absorption barriers. Most drugs used in anaesthesia are given by this route, it provides a reliable and rapid way of giving drugs. The speed of onset is the most rapid of any route, but is still dependent on the drug leaving the circulation to enter its site of action. Other factors can affect speed of action of iv drugs, particularly cardiac output. If intravenous induction agents such as thiopentone are given rapidly to a patient with a low cardiac output it is possible to give too much thiopentone inadvertently. This is because the drug does not reach and enter the brain as quickly as in a patient with a normal cardiac output and the onset of effect is delayed. It is tempting to continue

to give the drug until a response is achieved, by which time too larger a dose has been given.

Intramuscular/subcutaneous. Drugs may be given by injection into muscle or tissues. Absorption via this route does not occur at a constant rate and depends on the local blood supply. First pass metabolism is avoided. These routes are particularly unreliable in the shocked patient. In hypovolaemia the blood flow to the muscles and skin is reduced to preserve flow to essential organs. As a result little of the drug will be absorbed, when the circulation is restored drug may be absorbed rapidly. It is often safer and more reliable to give small doses intravenously in a shocked patient rather than risk the effects of intramuscular or subcutaneous routes. A good example of this effect is the use of morphine in a shocked patient, if given intramuscularly the patient may not experience any analgesic effect, as absorption is poor, later when the circulation is restored, there may be rapid absorption and respiratory depression. Small doses of morphine iv are a better and safer alternative.

Inhalational. This is useful in anaesthesia for volatile agents both for induction and maintenance of anaesthesia. Plasma levels rise rapidly, and this route is also used for drugs that have their site of action in the lungs such as salbutamol. It can be used as an alternative route to intravenous when no intravenous access is available for example at a cardiac arrest.

Topical, sublingual, rectal. These routes avoid the problems of first pass metabolism as the venous drainage does not pass through the liver. Topical application has become popular for local anaesthetic creams such as EMLA, and for patches such as fentanyl. These patches have complicated pharmacokinetics and their formulation is difficult and complex to provide a consistent uptake of drug.

DISTRIBUTION

Once the drug is present in the bloodstream, it will be distributed to all the tissues. The drug leaves the blood and enters the extracellular fluid and from there enters the cells. The drug moves down the concentration gradient. After an intravenous injection the amount of drug present in the blood peaks very rapidly; faster than we can detect with sampling. The plasma concentration then falls due to two continuing processes, distribution to other tissues and elimination by metabolism and excretion. These processes go on together, but distribution tends to cause the initial rapid fall in levels. It is logical that drugs will distribute to tissues with a high blood flow (heart, lungs, brain) most rapidly, then to those with a moderate blood flow (muscle) and finally to those with a poor blood flow (fat, tendons, cartilage) (Figure 1). The rate of fall slows, as distribution contributes less and elimination becomes the predominant process. If plasma concentrations are measured at regular times after an intravenous injection and plotted graphically the decline produced is exponential. (Figure 2). Exponential means that the rate of the fall of concentration depends on the amount of drug present. The process is known as **first order kinetics**. Most drugs behave in this way.

However, there are exceptions to the rule. If a drug is reliant on an enzyme system for its metabolism/elimination, then the enzyme system may be overwhelmed by the amount of drug and become "blocked" or saturated. Once the enzyme system is working as fast as it can to eliminate the drug, it cannot increase its rate even if the amount of drug delivered to it is increased. This means that the drug will be metabolised at a constant rate in spite of the amount of drug present. This is known as **zero order kinetics**. Graphically this appears as a straight line. Examples of drugs with zero order kinetics are ethanol, and high doses of phenytoin. The exponential process has certain characteristics, and these are used to characterise the pharmacokinetics of each drug. Each of these values can be measured, or calculated from the plasma concentration verses time curve.

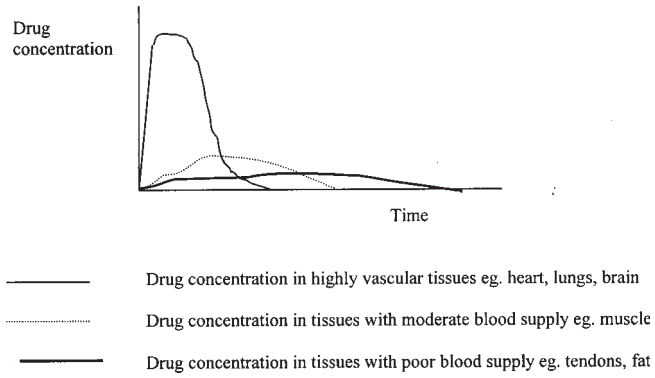


Figure 1. Drug distribution to different tissues

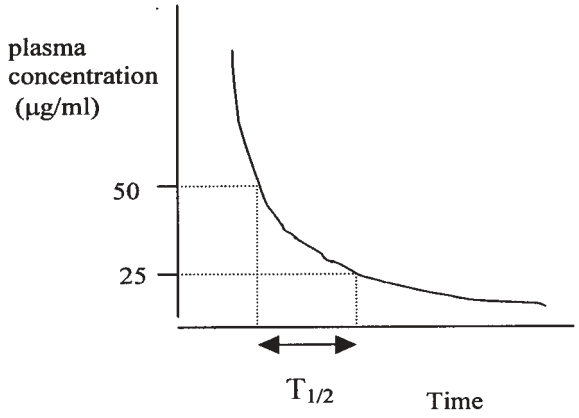


Figure 2. Plasma concentration/time curve. Showing the derivation of the half life

Half life (t1/2) is the time it takes for the concentration of the drug in the bloodstream to fall to half of its original value. The half-life is an important characteristic of the drug, as it defines the time interval between doses, and is very important in the design of infusion systems. Drugs given by infusion need to have, among other characteristics, a short half life.

Volume of distribution (Vd) is derived from the curve. It is not a real anatomical volume, but is the theoretical volume that the drug would be in if all the body had the same concentration as the plasma. It is calculated as follows:

$$Vd = \frac{\text{dose of drug given}}{\text{concentration of drug in blood at time zero on the graph.}}$$

In order to find the concentration at time zero accurately we employ a mathematical trick. The curve is an exponential, as we have said, and if we were to take logs of the concentration values (remember you cannot log time!) and plot them against time, the curve will become a straight line. The straight line allows us to accurately extrapolate back to the time zero position and read off the concentration. It is this Log plasma concentration verses time curve that is used to measure and derive the functions we use.

The Vd gives some idea of how fat soluble the drug is and how well it binds to proteins. In order to understand this, you need to think back to total body water (TBW) and the way it is distributed between different compartments (intracellular fluid, extracellular fluid, interstitial fluid). Extracellular fluid consists of interstitial fluid and plasma (15L), TBW = 60% of body weight, which is approximately 45 litres in an "average" man.

This is distributed as follows:

Intracellular fluid (30L)	Interstitial fluid (11.5L)	Plasma (3.5L)

The value for Vd varies from 5-1000 litres! Remember it is a theoretical and not an actual volume.

Vd = blood volume (5L) for drugs that are protein bound. These proteins are found in the blood and therefore the drug is limited to this compartment. eg. Warfarin, heparin.

- Vd approximates extracellular fluid volume (5-30L) for drugs that are ionised (have a charge). This is because these drugs are not very soluble in fat and cannot easily cross cell membranes to enter the intracellular fluid, but can easily diffuse out of the vascular space into the interstitial space thereby occupying the whole extracellular space. eg. Curare, gentamicin

- Vd is close to total body water (30-45L) for drugs that are highly fat soluble. These drugs are able to cross cell membranes to enter the intracellular fluid. eg. Phenytoin, ethanol, diazepam.

- Vd is greater than total body water (>45L) for drugs which enter cells and which bind extensively to tissue proteins. eg. Morphine, digoxin

Clearance is the volume of blood or plasma that is cleared of the drug per unit time. It is usually measured in millilitres per minute (ml/min). Clearance gives an indication of the ability of the kidneys and the liver to dispose of the drug. Clearance, volume of distribution and half-life are related to one another as follows:

$$t^{1}/_{2} \quad \alpha \quad \frac{Vd}{clearance}$$

This means that the time it takes for the drug concentration to fall is directly proportional to its volume of distribution and indirectly proportional to its clearance. In simple terms, this means that the half-life will be short if the drug has a small volume of distribution and is cleared fast (high clearance); the half-life will be long if the drug is widely distributed in the body (large Vd) and is excreted slowly by the kidneys and liver (slow clearance).

For example alfentanil which is relatively insoluble, has a small volume of distribution and has a very short half life. In contrast

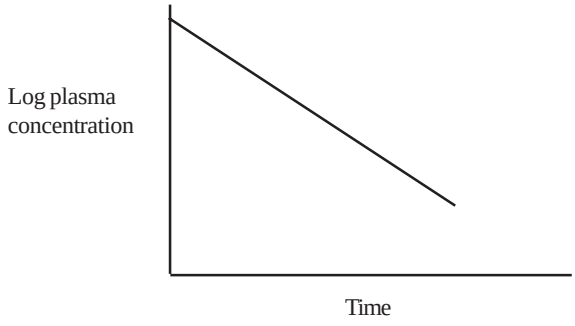
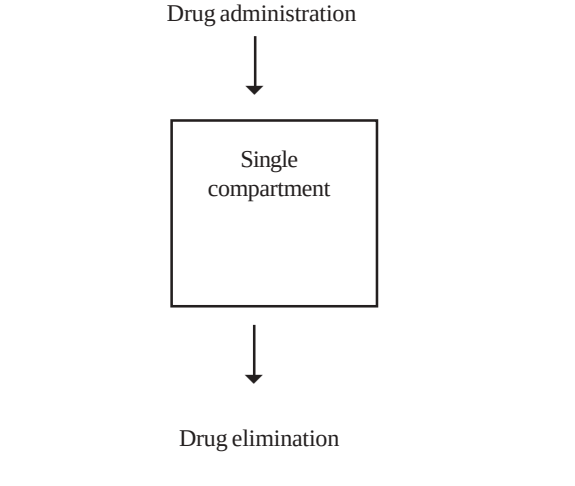


Figure 3: Log plasma concentration/time curve. Showing extrapolation to time zero, to obtain concentration at time zero.

remifentanil, a new potent opiate which has so short a half life that it can only be given by infusion, has a very brief effect due to rapid clearance of the plasma by metabolism by plasma esterases. A more traditional example would be suxamethonium, which is also brief in action due to metabolism by cholinesterase.

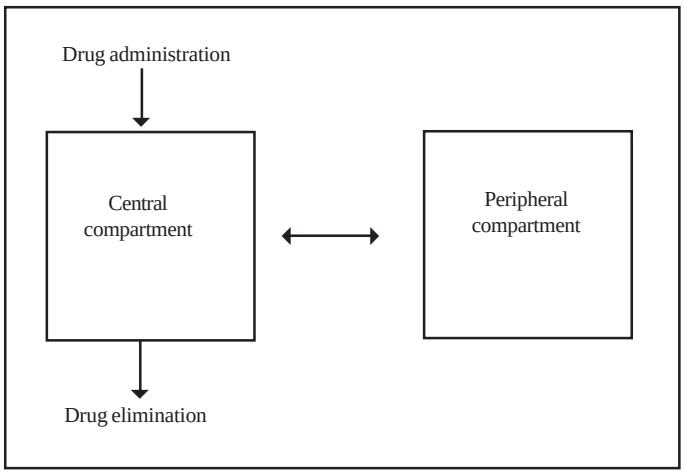
- **One compartment model** is a term mentioned frequently in books. This describes a theoretical situation in which the drug enters the plasma and is removed from it in a single, simple system. Drugs are administered into the single compartment and then eliminated from it by the kidneys and/or liver.



If we give an intravenous dose of a drug which is distributed only to the extracellular space, we could sample the plasma at intervals after administration and would see our exponential curve (figure 2). When we take logs of these concentrations we produce a straight line (figure 3), which indicates that one exponential process is involved the so called 'one compartment' model applies.

- **Two, or more compartment models**. In practice the models are more complicated, because the drug is not confined to the extracellular compartment and may enter other compartments

such as the brain, heart, muscles, these are well supplied with blood and may act as part of the central compartment. Other tissues, such as fat, bone, connective tissues may act as second, or even third and fourth compartments. The plasma concentration that we can measure then reflects movement of the drug in and out of all these compartments. Instead of a simple exponential, the process is made up of lots of exponentials! At this point the mathematics becomes very complex, and the log plasma concentration against time graph becomes a very complex connection of straight lines. It is important to remember that these processes, distribution out into the compartments, elimination via the kidneys and liver, and re-distribution back to the plasma from the compartments are going on all the time, it is no wonder the mathematics is complex.



ELIMINATION

For most drugs the kidneys or the liver achieves this process. However some drugs are excreted through the lungs, the skin or the breast milk, the latter being a route by which fat soluble drugs can be excreted. In order to be excreted through the kidney, the drug must be water soluble. Some drugs are excreted unchanged but the majority of drugs are metabolised in the liver to produce a water soluble and inactive form. The phase two process of metabolism, conjugation, usually renders the drug breakdown products soluble; glucuronide formation is an example. Drugs that cannot be rendered water soluble can be excreted in the bile, which contains sufficient cholesterol to dissolve the fat soluble products of drug breakdown. The bile passes into the jejunem, and there is the potential for re-absorption from the small intestine, and a prolongation of the half life. In anaesthetics, pancuronium and vecuronium are partly excreted in the bile.

The kidneys are responsible for the elimination of most drugs. Drugs are filtered by the glomerulus and excreted in the urine, and some drugs are actively secreted into the tubules. The rate of elimination will depend on the glomerular filtration rate, and like most biological processes it behaves in an exponential fashion.

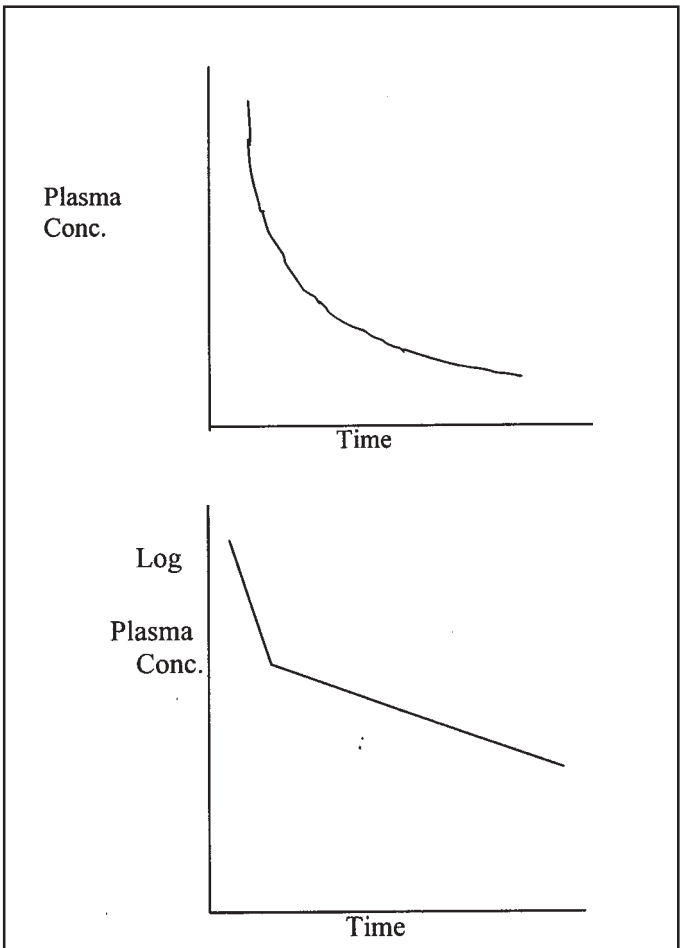


Figure 4: Pharmacokinetics of a two compartment model. The plasma concentration curve is a complex exponential, revealed in the log plasma concentration curve as two straight lines

DRAWOVER ANAESTHESIA REVIEW

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This paper discusses the equipment and role of drawover anaesthesia for the uninitiated 'plenum anaesthetist' while also delving into some of the finer aspects for experienced users.

Overview

Drawover anaesthesia is simple in both concept and delivery, has stood the tests of time, and travels well. The equipment is generally robust, versatile, easily maintained, and relatively inexpensive. Why, then, is it not more popular? Possible explanations are included in table 1.

History

Since the introduction of open drop volatile anaesthesia with ether, and later chloroform, anaesthetists have sought to refine vapour delivery in response to a variety of different clinical goals with different volatile agents. From an historical perspective, drawover and continuous flow (plenum) anaesthesia have been developed in parallel, ever since vaporisers first began to replace open drop methods at the turn of the 20th century.

What is drawover anaesthesia?

It is simply the act of drawing a carrier gas over a volatile liquid for the purpose of adding the vapour from that liquid to the carrier gas. This carrier gas/vapour mixture is then directed to the patient by a 'circuit'. In drawover systems the carrier gas is drawn through the vaporiser either by the patient's own respiratory efforts, or by a self-inflating bag or manual bellows with a one-way valve placed downstream from the vaporiser. Drawover systems operate at less than, or at ambient pressure, and flow through the system is 'intermittent', varying with different phases of inspiration, and ceasing in expiration. A one-way valve prevents reverse flow in the circuit.

This is different to plenum (Latin derivative, opposite to vacuum) anaesthesia in which a carrier gas is pushed through the vaporiser at a constant rate. In plenum circuits the anaesthetic is then collected in a circuit with a reservoir bag or bellows. Pressure fluctuations in the circuit caused by patient respiration, whether spontaneous or applied, do not involve or affect the vaporiser. Plenum systems operate at higher than ambient pressure.

The basic draw-over system is shown in figure 1.

Practical significance

Draw over systems are simple to assemble and use, and can operate without fresh gas supplies. They are lightweight and portable. Plenum systems are more technically complex, and need a well-regulated, constant, positive pressure gas supply. They require a more sophisticated anaesthetic 'machine' to support them. The transport of gas cylinders for plenum systems is both

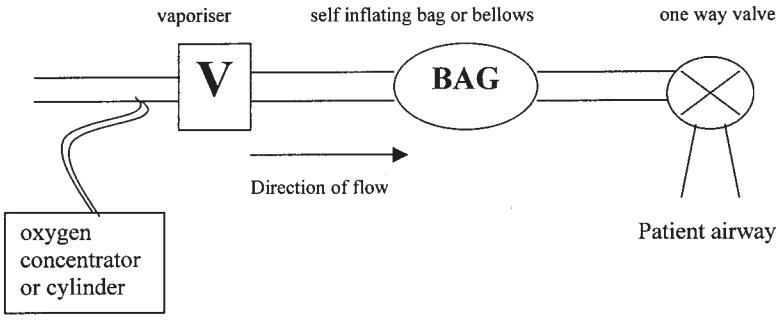

Figure 1: Basic draw-over components vaporise self inflating bag or bellows one way valve

Table 1 Drawover anaesthesia

Advantages	Disadvantages
Simplicity of concept and assembly, with inherent safety	Decreasing familiarity with the technique and equipment
No need for pressurised gas supply, regulators and flow meters	Vaporiser limitations
Minimum FiO_2 is ~21%	* Filling systems not agent specific (potential advantage)
Robust, reliable, easily serviced equipment	* Basic temperature compensation, affecting performance at extremes
Low cost (purchase and maintenance)	Less easy to observe spontaneous ventilation with self inflating bag
Portable, suitable for field anaesthesia	Cumbersome in paediatric use, unless lightweight tubing is available

expensive and potentially hazardous. Therefore drawover systems have obvious advantages in remote locations, in under-resourced countries, and in 'field/military' anaesthesia.

Supplemental oxygen?

In principle the 21% oxygen in air is diluted by the addition of vapour in the vaporiser, allowing a potentially 'hypoxic mixture' to be delivered to the patient. This is a theoretical issue, rather than a practical one, as the vapour concentration is small, and it is unlikely that the FiO_2 falls below 18%, the international standard for oxygen analyser alarms. It is more important to consider the respiratory physiological effects of general anaesthesia which tend to reduce ventilation and increase shunting of blood within the lung (V/Q mismatch). Therefore hypoxia becomes a clinical problem when using halothane or isoflurane with spontaneous ventilation (SV) in air, and supplemental oxygen is necessary [1,2]. The problem is reduced, but abolished, when applying intermittent positive pressure ventilation (IPPV). Ether can be delivered in air (without supplemental oxygen), in IPPV mode, presumably because it causes less intrapulmonary shunting and tends to stimulate ventilation, rather than depress it. When used in unsupplemented air with spontaneous respiration, some patients will desaturate.

In draw over systems supplemental oxygen is administered via a T-piece connection mounted to the intake port of the vaporiser. To maximise the inspired oxygen concentration (FiO_2) a 'reservoir tube' is attached to the T-piece, as shown in figure 1. A 1m length of corrugated tubing with an internal volume of 415ml allows an FiO_2 of at least 30% with an oxygen flow rate of 1.0 litre/min, and 60% at 4 litres/min, at normal adult minute ventilation[3]. With higher minute volumes the FiO_2 falls due to increased air dilution; at lower minute volumes the FiO_2 is higher. Oxygen may be sourced from cylinders, or an oxygen concentrator.[4,5,6]

The Houtonox oxygen flow control device is a simple, single stage reducing valve (regulator) that is suitably pin-indexed to fit directly to an oxygen cylinder. Adaptors for bull-nose connections are available. Flow rates that can be set are fixed at 1 and 4 litres/min, which are ideal in combination with draw over systems[7]. The device is accurate and sturdy, and allows maximum benefit from limited oxygen supplies.

Equipment used in Drawover Anaesthesia

Vaporisers

The ideal drawover vaporiser needs to have low internal resistance to gas flow to allow easy spontaneous ventilation, while vapour output should be constant for a given dial setting over a wide range of minute volumes and ambient temperatures. Other desirable qualities are that the circuit connectors comply with international standards and that chamber filling is visible. These requirements determine careful vapour chamber design. Wicks can be used to increase the area of the volatile liquid:carrier gas interface but their presence, size and complexity is limited by the internal resistance to gas flow created. The need for saturated vapour output is balanced against the resistance created, and is simply not achievable in all possible working conditions in draw over mode, particularly at extremes of tidal volume or in cold environments.

Plenum vaporisers, with their constant driving pressure and predictable flow rates can afford increased internal complexity and resistance. Modern plenum vaporisers still have performance limitations at extremes of flow rate and temperature, but they are generally more accurate than their draw-over counterparts.

As vapour is liberated the temperature of the liquid volatile agent falls due to the latent heat of vaporisation. This causes a fall in the saturated vapour pressure and lowers the output of the vaporiser. Temperature compensation is managed in two basic ways. The first is to provide a large heat-sink of conductive material (water bath or mass of metal), the dimensions of which are limited by size and portability. Heat is conducted from the heat-sink to the volatile liquid and minimises the fall in temperature of the liquid agent. The second method is to vary the vapour chamber output with temperature, so that more carrier gas is allowed to pass through the vapour chamber as the temperature falls, and less as it rises. This is achieved by bimetallic strips and ether-filled bellows in plenum vaporisers, but they cause an increase in the internal resistance. Some drawover vaporisers have basic thermo-compensation devices incorporated (EMO, PAC). In clinical practice a fall in vaporiser output may be compensated for by an increased dial setting.

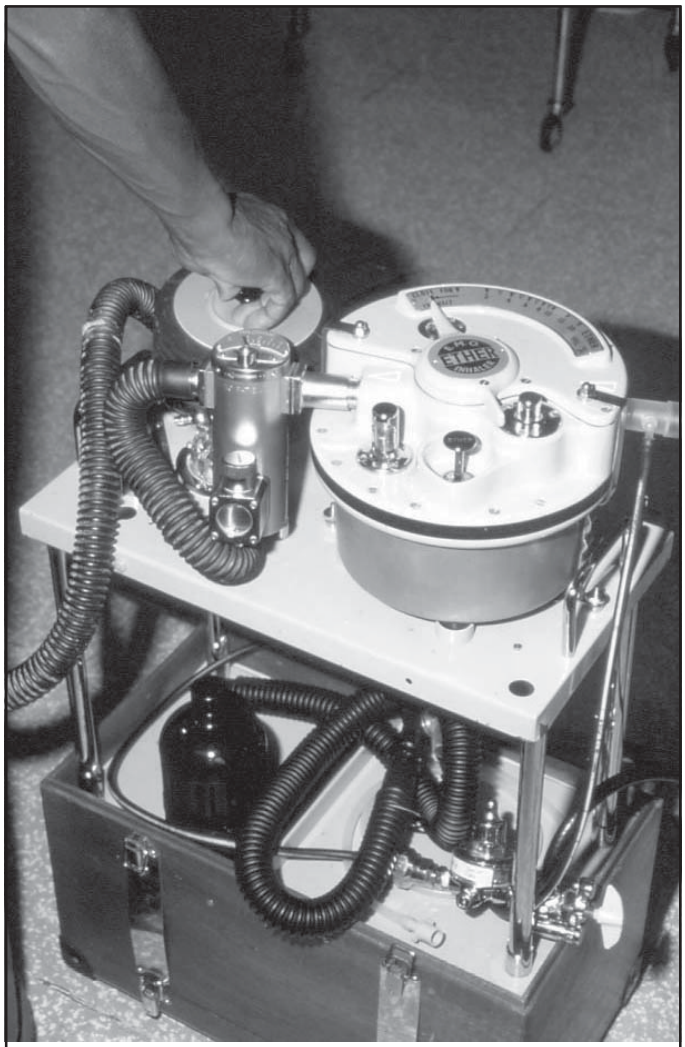

Figure 2. EMO and OMV being used for drawover anaesthesia

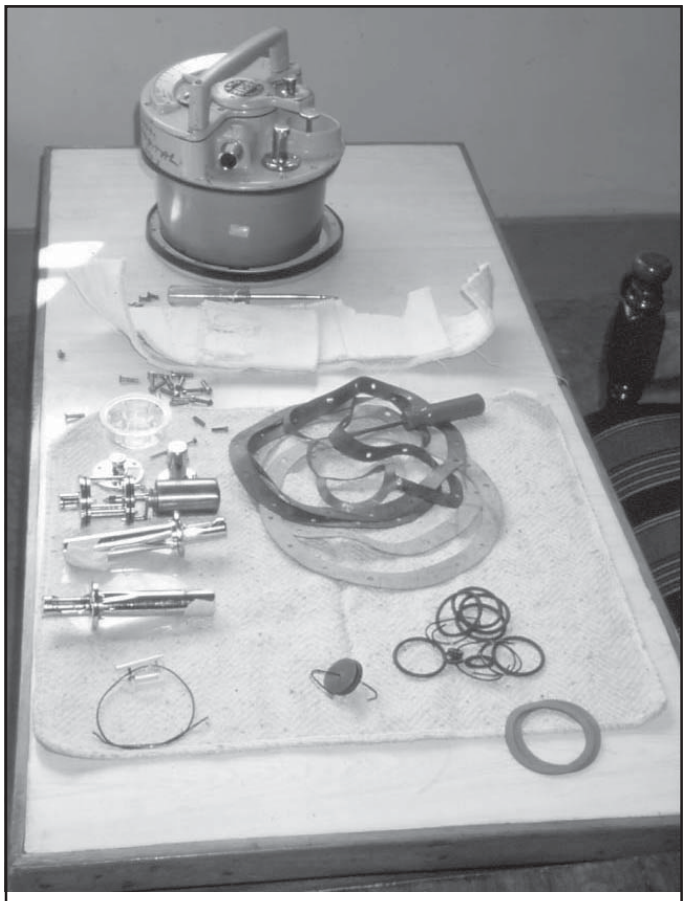

Figure 3: EMO stripped down for maintenance

Drawover vaporisers theoretically should not be used in plenum fashion, as the output may not reflect the dialled setting. This problem is more significant with some vaporisers, and is greatly influenced by both flow rate and temperature. This is considered under each vaporiser heading.

Most plenum vaporisers cannot be used for drawover anaesthesia because of their high internal resistance.

EMO (Epstein Macintosh Oxford; Penlon; figure 2) is a classic design, unmodified since the 1950's, which testifies to its design and capabilities [8]. It is designed for use with ether and is damaged by halothane. Stripping and maintenance is straightforward (figure3). A key component is the temperature compensating device, which is a sealed cannister containing liquid ether attached to a spindle, automated by opposing springs. The splitting system comprises two concentric brass cylinders with apertures, one of which rotates with the dial setter, thus altering the overall ratio between vapour chamber and bypass flow. An expensive setting gauge is available from Penlon to position the splitting device correctly. A 0.1 inch (2.6mm, 8 French gauge, 12 Stubs needle gauge) wire is an approximate substitute. To calibrate the dial properly one must loosen the central screw, and place the dial in the 6% position. The setting gauge is placed in the aperture, through the temperature compensator portal, and the screw is tightened until the gauge is lightly gripped. The vaporising chamber sits in a water bath, which acts as a heat sink. This can be emptied for transport[8]. The entire EMO set-up weighs over 10kg, limiting its potential for field use. In plenum mode the EMO only begins to perform reasonably accurately with flow rates around 10 l/min, and is therefore not ideal for paediatric use with a T piece, although circuit adaptations can be made[9,10]. If used in "pushover' fashion, with a ventilator or bellows placed upstream, the output can significantly exceed the dial setting.

OMV (Oxford Miniature Vaporiser; Penlon; figure 4). This vaporiser is the most portable and most versatile drawover vaporiser, but its size does impose performance limitations. The vapour chamber, which contains 50mls of volatile agent, empties quite rapidly when in use. It is suitable for a number of agents, a feature assisted by interchangeable dial scales, and has basic thermal buffering in the form of a small glycol (anti-freeze) reservoir within a metal heat sink[7, 11]. It suffers a reduction in vapour output at lower temperatures, with a maximum output varying from 2-4% with halothane between 0-30^{O}C, and higher above this. Made from stainless steel, it is resistant to corrosion by volatile agents. Metal mesh wicks increase the output without significantly increasing the internal resistance. The unit needs little regular maintenance. A common problem encountered with the OMV is that the dial becomes stiff from thymol being deposited in the mechanism during use with halothane. Thymol may be dissolved by putting ether in the OMV and shaking it whilst working the lever back and forward - remember to empty the unit afterwards! Alternatively strip and clean the mechanism (if you have been trained).

It is common to use 2 OMV's in series to augment the output, as is standard in the Triservice apparatus, which was originally used with trichloroethylene in one and halothane in the other. The standard field anaesthetic machine of the Australian Defence Forces uses two Oxford Miniature Vaporisers (OMV's) in series in either draw over or in true plenum mode (i.e. with continuous flow gases fed in upstream), depending on the circuit attached. It can operate efficiently as a plenum vaporiser in anaesthesia and

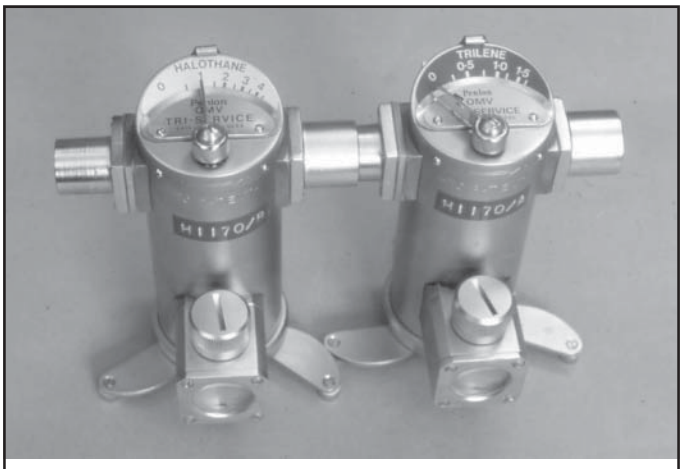

Figure 4: Oxford miniature vaporisers - Triservice nodels

ICU[12,13]. Output reflects dial settings at 25^{o}C, in either continuous flow or draw over use, but falls dramatically at 150^{o}C, and rises steeply when above 35^{o}C[14]. The reduction in output associated with the fall in vaporiser temperature during use may require an increase in dial setting, as determined clinically. Keeping the vaporiser topped up with fresh liquid at room temperature helps maintain the output.

The OMV is reasonably accurate over a wide range of flow rates and tidal volumes and, in particular it performs well at small tidal volumes, making it suitable for paediatric anaesthesia [14,15]. The OMV has also been used in a circle system. However due to its efficiency it is capable of producing very high concentrations and is not recommended for this use.

PAC (Portable Anaesthesia Complete; Datex-Ohmeda. Now called TEC). Originally released as a series of individual vaporisers designed for specific volatile agents[16]. A multi-agent version, the Ohmeda Universal PAC, is now also available suitable for use with halothane, isoflurane, enflurane, and diethyl ether. The apparent intention was to manufacture the draw-over vaporiser with the best (linear) output performance profile over a wide range of conditions, and that task has been achieved in adult use. Accuracy is enhanced by a bimetallic strip temperature compensating device, and there is a built in T-piece for oxygen supplementation. Unfortunately the output is less accurate at small tidal volumes, or when used as a plenum vaporizer with gas flows below 2-4l/min. Therefore it is not as useful for paediatric anaesthesia.[14,16] It comes in a sturdy carrying case, and has for many years been the standard issue field vaporiser used by the US military and has been very widely used in Malawi[17,18]. In summary it is an excellent vaporiser, particularly for adult draw over use. Regular servicing is recommended.

Self Inflating Bags/Bellows

Oxford Inflating Bellows (OIB) come as standard with the EMO system (figure 2). The bellows sit vertically with a residual internal volume maintained by a spring. This arrangement allows movement of the bellows during spontaneous respiration providing a useful indicator of breathing. The OIB was originally designed for use with a simple spring loaded valve (eg Heidbrink valve). To facilitate gas flow through the OIB there are two one-way valves in the form of metal discs on circular seats. This arrangement works well for spontaneous ventilation (SV), but is less than satisfactory for intermittent positive pressure ventilation (IPPV) as adjustment of the Heidbrink valve must be constantly revised. Non-rebreathing valves of either the Laerdal or Ambu type (figure 5) can be used more effectively at the patient end of the draw over circuit to facilitate IPPV, and are equally suitable for SV.

One note of caution is that with this adaptation the OIB is prone to jam unless the downstream valve on the OIB is disabled with the magnet provided (figure 6). When the OIB jams the patient cannot exhale as an air-lock develops between the non-rebreathing valve and the OIB valve. The patient must be disconnected from the circuit to allow exhalation. This problem is more common with IPPV, but may also occur in SV use. When in use the magnet holds the distal OIB flap valve in the open position and stops the air-lock developing. Some anaesthetists even remove the downstream disc to prevent this problem. A simpler, single flap valve bellows called the Penlon Bellows Unit, PBU, has been developed to address this issue, and to avoid confusion concerning when the magnet should, and should not be used. If in doubt, it is useful to remember that when using MODERN valves, use a MAGNET.

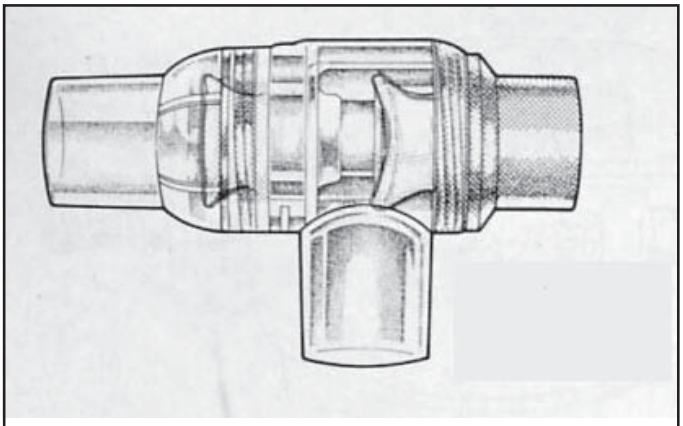

Figure 5. AMBU E1 anaesthesia valve

The tap on the side of the OIB is intended for connection to supplemental oxygen when using the bellows for resuscitation purposes. During anaesthesia, however, it is preferable to leave this closed and supply oxygen upstream of the vaporiser. Adding oxygen at the bellows dilutes the anaesthetic vapour.

To operate the bellows to assist ventilation the recommended manoeuvre is a rocking motion, rather than direct up and down. This creates less fatigue over time, and produces less variability in tidal volume. The movement of the bellows during IPPV is characterised by three phases: down, up, pause.

Laerdal, Ambu or other self inflating bags are considered together as there is little practical difference between them. Their valves are used to create the one-way flow in the circuit, and are attached to the patient's airway to minimise rebreathing. The bag can be separated from the valve by a length of 22mm anaesthetic tubing to allow it to sit better. The inflow side of the bag needs to be arranged so that all gas is drawn through the vaporiser, and no air entrainment is allowed, which would dilute the anaesthetic and potentially lead to awareness. Spontaneous ventilation does not cause a movement of the bag unless there is a fault in the draw over circuit causing a resistance upstream. To observe gas flow in the circuit, tape a fine feather or piece of paper at the inflow end of the whole system.

One Way Valves

The non-rebreathing valve (usually an Ambu valve or Laerdal valve) should be placed as close to the patient's airway as possible to minimise the apparatus dead-space. Both valves can be scavenged. A Heidbrink valve, or similar spring loaded blow-off valve, (which is not one-way) can be used downstream of an Oxford Inflating Bellows during spontaneous respiration, providing both OIB valves are functional. The magnet should not be used to disable the valve in this instance.

Connecting tubing

The connecting tubing of a draw over circuit is standard 22mm tubing. Antistatic tubing is required for ether, otherwise lightweight plastic tubing is more convenient.

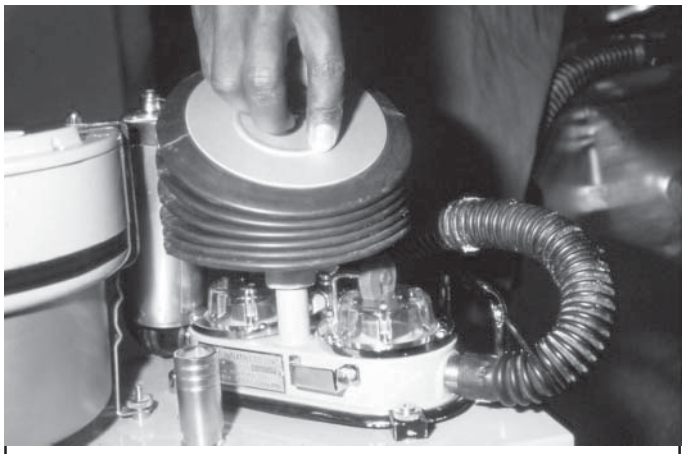

Figure 6: Magnet in place on the Oxford Inflating bellows

Conducting A Draw-Over Anaesthetic

Intravenous induction

This is performed as normal and the airway maintained in an appropriate fashion. Face masks, endotracheal tubes and laryngeal mask airways are all suitable for drawover anaesthesia.

Inhalational induction

During an inhalational (gaseous) induction a seal is required between the face and the mask, or gas will not be drawn through the vaporiser. When this occurs the patient will breathe room air around the mask and remain conscious!

In adult anaesthesia it is relatively easy to coax a mask on the face and still keep the patient calm and cooperative. A benzodiazepine and/or opioid premedication will assist with this in anxious patients, and markedly improves the tolerance to pungent volatile agents such as ether or isoflurane. Problems may arise with elderly, edentulous patients in whom masks may not fit well, or males with heavy beards in whom the seal is hard to maintain. Filling the beard with lubricant jelly does help, but makes the mask very slippery. A defibrillator pad or transparent sticky plastic dressing with a hole cut in it fulfils the same need and is easier to hold.

In paediatric use the problem is two-fold. The child may be uncooperative so that maintaining a mask seal is difficult (and sometimes psychologically traumatic). Small children (<15kg / 3 years) may not generate sufficient tidal volumes to draw vapour into the circuit through the one-way valves, so even the cooperative ones may be slow to induce!

One solution is to enlist an assistant to operate the bellows (or self-inflating bag) to prime the circuit and bring vapour up to the mask. Continued operation of the bellows will create flow through the circuit and keep the supply of vapour coming, and the induction can be done as if using a plenum anaesthetic system. The mask seal will not be as important.

Adaptation of the drawover system to use with a standard Ayre's T-piece circuit is also possible for the very young. This is done by connecting the T piece to the outlet of the OIB[19,20]. The fresh gas flow is provided by the assistant slowly operating the bellows 6 - 8 times a minute and the T piece is used in the normal fashion. The distal valve should be operational for this system to be used. Paediatric drawover techniques are not detailed in this review.

Maintenance of anaesthesia

Spontaneous ventilation has several advantages, especially when using new or unfamiliar equipment and leaves the anaesthetist's hands free for other tasks. The volatile agent has to be delivered at higher values to compensate for the absence of nitrous oxide. Parenteral opioid analgesics should be provided, again titrated to signs of anaesthetic depth. Alternatively supplementation by regional anaesthesia may be effective.

Neuromuscular blockade requires the patient to be ventilated. This can be done manually, or through the use of a suitable 'draw-over ventilator', such as the Manley Multivent (Penlon UK; figure 7).

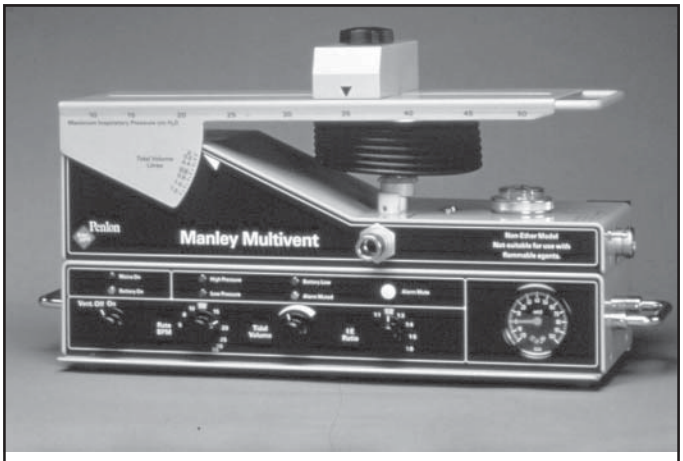

Figure 7: Manley Multivent

Volatile Agents (*See also Update in Anaesthesia No 11 - Volatile Anaesthetic Agents*).

Ether is still available in many parts of the developing world, and where medical supplies are restricted industrial grade ether may be successfully used. Unfortunately it is flammable in air, and explosive in oxygen and can be ignited within a 25cm radius of a source of ether vapour "zone of risk". Provided sensible antistatic precautions are taken to prevent any sources of sparking / ignition within this zone ether may be safely used. During ether anaesthesia diathermy should not be used in the airway, chest or upper abdomen. Ether possesses excellent anaesthetic and analgesic properties. It has a low potency which results in a prolonged inhalational induction with a well described excitement phase. For this reason ether anaesthesia is easiest provided following an intravenous induction. The OMV was originally designed to assist with ether induction by additional use of halothane. It is placed downstream of the EMO, and an OMV setting of 1% greatly speeds induction, taking less than 10 minutes. The halothane can be turned off when the ether concentration reaches 12 -15%.

Halothane (Fluothane) is widely available and relatively inexpensive. It ranks highly as the agent of choice for use in children. Although it slowly degrades some metals in the anaesthetic equipment, and absorbs into rubber components of

the circuit, it is an excellent agent that has been used for nearly 50 years. Halothane contains thymol which coats moving parts in the splitting system, and builds up on wick devices, but can be removed with application of ether - see under OMV.

Trichlorethylene (Trilene) has a relatively low anaesthetic potency but provides good analgesia. In the Triservice apparatus (Penlon) trichlorethylene and halothane were traditionally used in series. It is becoming harder to source, although chemical reagent trichlorethyelene is sometimes available.

Enflurane (Ethrane) is an agent that has rapidly been phased out in many parts of the world after brief popularity in the 1980's. It is still in use where economic factors favour it. It can be used for inhalational induction and maintenance. Its main disadvantage is its propensity to induce epileptiform phenomena, particularly with hypocarbia and in children. Two OMV vaporisers are required to provide adequate concentrations for induction.[21]

Isoflurane (Forane) has the same saturated vapour pressure as halothane, and is thus theoretically suitable for use in any vaporiser designed for halothane.[22] Gaseous induction with isoflurane is impaired by its relative pungency and airway irritative properties. With benzodiazepine and / or opioid premedication, and a gentle approach, this is an easily surmountable problem. Isoflurane has come down in price since its patent expired.

Sevoflurane (Sevorane) has been used in draw-over, but its use is hampered by a need to deliver high percentages which are at the upper limits of simple vaporiser performance capabilities, as well as its high cost. Using additional wicks to maximise output can be helpful, but latent heat of vaporisation rapidly cools the system and lowers performance. Two OMV vaporisers are required to provide adequate concentrations for induction.[22]

Right agent, wrong vaporiser?

Some vaporisers (OMV and TEC) are designed for use with different agents and a variety of scales are provided to allow this. Care should be taken that agents (eg ether, trichlorethylene and halothane) are not mistakenly put in the wrong vaporiser, or the wrong dial used.

Conclusion

Draw-over anaesthesia holds distinct advantages in less affluent hospitals where the advantages over any other form of anaesthetic delivery system are not only economic, but also practical, and the training required to deliver safe anaesthesia is kept to a minimum. During field anaesthesia the added attractions of portability and reliability allows rapid and effective deployment of anaesthesia equipment to the area of need. Field anaesthesia, such as that performed by the military and humanitarian organisations, is greatly simplified by combining draw-over and intravenous techniques. Major surgery is made possible that is undoubtedly life saving. In the first world hospital, exposure of trainees to draw-over techniques results in a deeper understanding of equipment and more skilled anaesthetist.

Our thanks for the constructive and expert assistance with this article given by Dr Haydn Perndt, Staff Anaesthetist and Course Director of "Remote Situations, Difficult Circumstances, and Developing Country Anaesthesia" Course, Royal Hobart Hospital, Tasmania, Australia.

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BOOK REVIEW

Our Editor has been sent the accompanying review of the Oxford Handbook of Anaesthesia. It expresses the view of a well known anaesthetist in Africa. I have told him that it should be published as it gives a viewpoint from a training centre in Africa. I have heard similar favorable comments in Australia. It is a very useful and compact book, full of information.

Kester Brown
President - World Federation of Societies of Anaesthesiologists

Book Review

Oxford Handbook of Anaesthesia - Editors Allman and Wilson, ISBN 0 19 263273 6 Oxford University Press 2002, UK (www.oup.com), UK price £22.95, South Asia Indian Rupees 450. Available to readers in developing countries at a specialprice from Teaching Aids at Low Cost, talc@talcuk.org

I am not usually happy having much to do with books termed handbooks and short lecture notes. They often give you a taste when you need a good meal, but the new Oxford Handbook of Anaesthesia (OHA) edited by Drs.Allman and Wilson is not in that style. This handbook is exceptional value and is more like a concise comprehensive reference textbook with authoritative advice and is in a very readable format. I am sure it is going to be much sought after in many different parts of the world.

The OHA has been an instant success among our students doing the one year course in Anaesthesia in Uganda. For them its cost at £22 (US$ 33) is a major proportion of their limited salary yet the majority of the current class have made me put in an order on their behalf. They are aware that the contents at this time are more than they require but they have discovered a reference book which is going to serve them well in years to come.

In the first world setting I am sure this book is going to be a major asset to residents and teachers and to the experienced practitioner who needs to be up to date in the sub speciality with which he or she only occasionally deals. To get a concise but comprehensive overview from a modern text book is not easy. It is often hard to see the wood for the trees and the information technology revolution has not given us the discerning judgements that are the foundation of good practice. The editors have given us an appropriate conciseness which is only possible with good judgement. The book has 1139 pages and it will fit into the pocket of a white coat but only just. There are 50 chapters divided into 7 sections. The sections include preoperative care, anaesthesia for the surgical specialities, obstetrics, paediatrics, emergency management, acute pain management, and regional blocks. The frequent lists for suggested reading are particularly useful for the reader wishing to go deeper. The format is ideal for the busy practitioner with paragraphs in bold headlines and each concise sentence packed with clear guidance. It is bound in a sturdy plastic cover that will survive many years of use.

I would have been happier to see ether included in volatile agents discussed, after all for a great part of the world this is the anaesthetic of choice and sometimes the only one available. Also perhaps a chapter on ketamine and some basic cardiorespiratory physiology would have made it more suitable for the novice and the teacher in this part of the world. However it will be my major reference book for the foreseeable future. It should be in every theatre and of course every library and I am sure it will become the personal property of many busy anaesthetists in many parts of the English speaking world.

Dr Raymond Towey, Consultant Anaesthetist
St.Mary's Hospital Lacor, Gulu, Uganda

SELF-ASSESSMENT QUESTIONS

Dr Rob Law, Consultant Anaesthetist Royal Shrewsbury Hospital, Shrewsbury, UK and Dr Ed Hammond, Royal Devon and Exeter Healthcare NHS Trust, Barrack Road, Exeter, Devon, EX2 5DW, UK.

Question 1
Epiglottitis
A. Is commonest in children between six months and three years
B. There may be no systemic upset in the child
C. Cannulation is mandatory before attempting to control the airway
D. Staphylococcus is the usual causative organism
E. Intubation for 24hours is usual

Question 2
When assessing the airway preoperatively
A. The Mallampati grading accurately predicts difficult intubation
B. Mallampati grade 4 indicates a view of the soft palate
C. Wilson grade C accurately predicts difficult intubation
D. The ability to put chin on chest is a reliable indication of ease of intubation
E. Vertebro-basilar insufficiency may be detected

Question 3
Porphyria
A. Can be induced by alcohol, pregnancy and muscular activity
B. Is characterised by the induction of the enzyme d-aminolaevulinic acid synthetase
C. Anaesthesia does not induce the erythropoetic forms of the disease
D. The use of tourniquets is contraindicated
E. Barbiturate anaesthesia must be avoided

Question 4
The American Society of Anesthesiologists (ASA) Physical Status
A. Predicts postoperative outcome
B. Was instituted in response to malpractice claims
C. ASA Class II would include a well-controlled asthmatic
D. ASA Class IV indicates a condition which impedes activity but does not represent a threat to life
E. Postscript E indicates an elective case

Question 5
In ketoacidotic diabetic coma
A. Large volume administration of dextrose-containing solutions are required in resuscitation
B. Potassium supplementation will be required
C. The hourly insulin requirement can be calculated by dividing the daily requirement by 24
D. Bicarbonate therapy is needed with an arterial pH above 7.0
E. Artificial ventilation may be required

Question 6
The Glasgow Coma Scale
A. Indicates the severity of head injury
B. May be used as a prognostic guide
C. A score of 2 is incompatible with survival
D. If the patient's best motor response is flexion to pain, this scores 3 points
E. Was first described by Dr Fergus Glasgow in 1973

Question 7
The following are early signs of inadvertent oesophageal intubation
A. ST depression on electrocardiogram (ECG)
B. Bradycardia
C. Absence of waveform on capnograph
D. Absence of breath sounds on auscultation of lung apices
E. Oxyhaemoglobin desaturation detected on pulse oximetry

Question 8
Postoperative shivering
A. Is due to the use of volatile anaesthetic agents
B. May cause hypoxia in recovery
C. May be arrested by a single dose of 25mg pethidine intravenously
D. Does not occur after spinal anaesthesia
E. The incidence of shivering with extradural analgesia is reduced by the concurrent use of an opiate

Question 9
Intravenous regional anaesthesia (Bier's block)
A. Can safely be performed using 0.25% bupivacaine without adrenaline
B. Provides good quality postoperative analgesia
C. Depends on the use of a double-cuff tourniquet inflated to 50mmHg above systolic pressure
D. The tourniquet can safely be deflated 20minutes after injection
E. An advantage of the technique is that it can be employed by unsupervised casualty officers

Question 10
The following agents may be used safely in a patient with asthma
A. Vecuronium
B. Ketamine
C. Atracurium
D. Tubocurarine
E. Isoflurane

Question 11
The following commonly occur in pulmonary embolism
A. Left bundle branch block
B. Dyspnoea
C. Raised systolic blood pressure
D. Bradycardia
E. Cannon waves in the JVP

Question 12
The following are recognised complications of massive transfusion of stored blood
A. Hypokalaemia
B. Hypernatraemia
C. Tetany
D. Hypothermia
E. Thrombocytopaenia

Question 13
The following tests are useful during acute investigation of a case of suspected anaphylaxis
A. Serum histamine
B. Serum N-methylhistamine
C. Serum tryptase
D. Serum IgA
E. Serum complement

Question 14
During anaphylaxis
A. Bronchospasm will occur in more than 75% patients
B. Bronchospasm may be the only presenting feature
C. Disseminated intravascular coagulation (DIC) may occur
D. More than 10% of reactions involve upper airway oedema
E. Cardiovascular collapse may be the only clinical feature

Question 15
In the patient with an ejection systolic murmer
A. The patient with aortic stenosis has an increased risk of perioperative mortality
B. Two dimensional echocardiography is used to assess gradient across the valve
C. Aortic gradients greater than 25mmHg are regarded as significant
D. The patient will require antibiotic cover perioperatively
E. An aortic gradient less than 50mmHg excludes severe aortic stenosis

Question 16
The following clinical associations are correct
A. Plasma potassium 2.6mmol/l - ST depression on ECG
B. Plasma sodium 114mmol/l - bronchial carcinoma
C. Plasma calcium (corrected) 3mmol/l - prolonged QT interval on ECG
D. CSF glucose 1mmol/l with plasma glucose 6mmol/l - bacterial meningitis
E. Serum albumin 60g/l - trauma

Question 17
Considering malignant hyperthermia during anaesthesia
A. Sevoflurane is a precipitant
B. The incidence is about 1 in 50,000 anaesthetics
C. Inheritance is by an autosomal dominant mechanism
D. Mannitol is added to vials of dantrolene to aid management of haemoglobinuria
E. Profound muscle weakness can result from the effect of dantrolene on calcium transport

Question 18
In a patient with sickle cell anaemia
A. About 50% of their haemoglobin will be in the HbS form
B. Exchange transfusion is appropriate prior to major vascular surgery
C. Folate is contra-indicated perioperatively as it may provoke an aplastic crisis
D. The Hb-O_2 dissociation curve is shifted to the right aiding tissue O_2 unloading
E. The use of any tourniquet is absolutely contraindicated

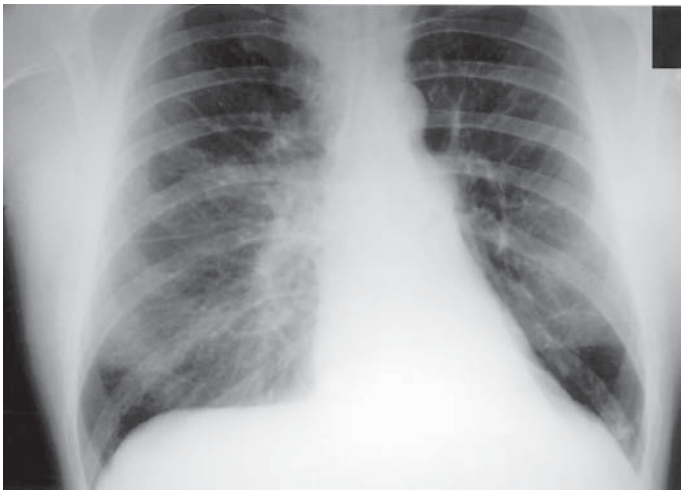
Question 19
During anaesthesia for a patient with severe mitral stenosis
A. Sinus rhythm is critical since atrial contraction contributes 60% of ventricular filling
B. If a-v pacing is required a long P-R interval is appropriate
C. Afterload reduction is appropriate even if systemic blood pressure is normal
D. Increased pulmonary vascular resistance is not a likely problem
E. There will often be a marked discrepancy between PA diastolic and PA wedge pressures

Question 20
In a patient with severe aortic stenosis undergoing a general anaesthetic
A. There is a direct relationship between calculated aortic valve area and blood flow across the valve
B. A peak aortic valve gradient of 30mmHg is not compatible with the diagnosis
C. A faster heart rate will be important to help left ventricular filling
D. A reduction in systemic vascular resistance has little effect on ventricular emptying
E. Episodes of myocardial ischaemia should be treated with GTN

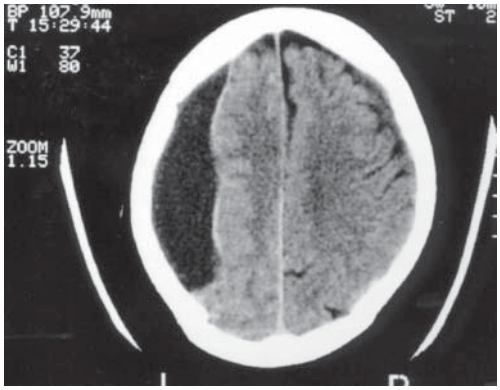
Question 1.
You are the anaesthetist covering an obstetric unit. You and the obstetrician are called urgently to a patient. A primigravida woman with an antenatal diagnosis of intra-uterine growth retardation is being induced at 35 weeks gestation. She has received prostin pessaries overnight, and after starting the syntocinon infusion, develops prolonged late decelerations on the cardiotocograph (CTG) trace. Her cervix is 3cm dilated, she is contracting strongly and has received only intramuscular pethidine as analgesia.

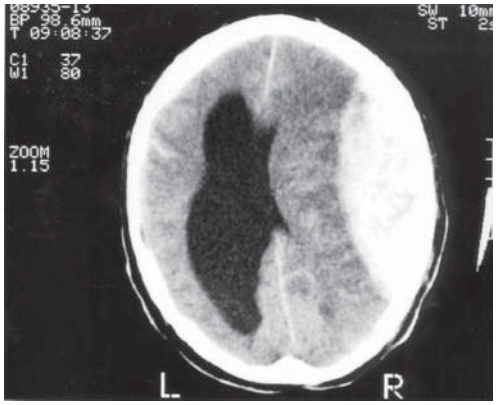
- Describe the significance of the tracing
- How would you manage this patient?
- Outline the physiology of fetal oxygenation

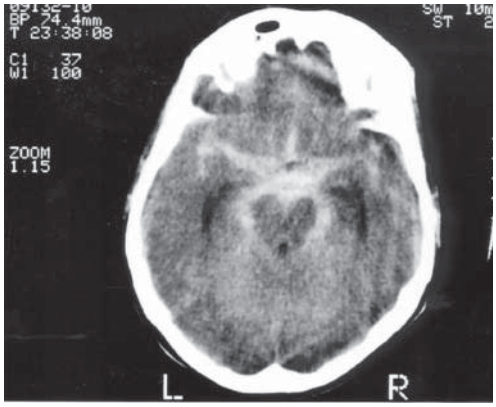
Question 2.
You are asked to anaesthestise a 25 year old man for an appendicectomy. He is a smoker who has recently had a chest infection that has been treated with antibiotics by his general practitioner. He still has a productive cough but is not short of breath and on examination he has some coarse crepitations in both lung fields. His pre-operative chest X-ray is entirely normal. After an uneventful procedure under general anaesthesia you extubate him and transfer him to the recovery ward. You are called back to recovery because his oxygen saturations are only 87% despite a high inspired oxygen concentration and he is complaining that he is having difficulty breathing. You examine him and order a chest X-ray (shown). What is the diagnosis and how would you treat it?



Question 3.
What pathology is demonstrated in each of these three CT scans?







ANSWERS TO MCQ QUESTIONS

Question 1

A. false B. false C. false D. false E. true

Epiglottitis causes a severe systemic upset with fever and drooling, which contrasts with croup where the child may otherwise be well. Croup is seen between six months and three years. Over this age epiglottitis is more likely to be responsible. Cannulation, direct examination and X-rays should not be attempted as laryngospasm may occur. Short term intubation, initially facilitated with sedation but not paralysis, is usually required and the causative organism is Haemophilus; bacterial tracheitis, which is a differential diagnosis, is caused by Staphylococcus.

Reference: Johnston D, Hull D. Essential Paediatrics, 3rd edn. Churchill Livingstone, 1994

Question 2

A. false B. false C. true D. false E. true

The Mallampati system detects only 50% of difficult intubations. Grade 1 allows a full view down to the tip of the uvula, grade 2 the base of the uvula, grade 3 the soft palate only and grade 4 is where the soft palate cannot be seen. The Wilson test is of ability to protrude the mandible below the maxilla, where A is the mandible beyond the maxilla, B is where they can be aligned, and C is where the mandible cannot be brought in line with the maxilla. Neck extension is more important than flexion, and may reveal vertebro-basilar insufficiency in the susceptible.

*Reference: Recognition and management of difficult airway problems. Cobley M, Vaughan R. British Journal of Anaesthesia 1992;**68**:90-97. Also Update in Anaesthesia Issue 9.*

Question 3

A. false B. true C. true D. false E. true

Acute porphyric attacks are induced by alcohol, diet, pregnancy and in the case of the hepatic forms of the condition by barbiturates and steroids. Induction of d-aminolaevulinic acid synthetase with a deficiency of an enzyme further down the pathway of haem synthesis underlies all forms. Tourniquets, hypoxia and acidosis induce sickle crises not porphyria. Safe anaesthesia includes propofol, vecuronium, opiates and domperidone. Volatiles are probably not safe, and the use of local anaesthetic agents is contentious.

*Reference: Harrison et al. Anaesthesia for the porphyric patient. Anaesthesia 1993;**48**:417*

Question 4

A. false B. false C. true D. false E. false

The ASA classification does not predict outcome; it indicates preoperative status and suggests the degree of skill required to deal with the case. It is widely used in audit to indicate the severity of disease and in research to standardise patients. The Harvard Minimum Monitoring Standards were developed as a result of escalating malpractice premiums. E indicates emergency, but has a different definition from that used in the Confidential Enquiries into Perioperative Death.

The ASA classes are, briefly:

I: Fit and well
II: Mild systemic disease
III: Disease restricting activity
IV: Severe systemic disease which is a constant threat to life
V: Moribund and not expected to survive 24 hours.

Reference: Update in Anaesthesia No 14

Question 5

A. false B. true C. false D. false E. true

Severe cases require intensive care management and frequently require intubation and ventilation. The condition may be insidious in onset, caused by infection, infarction or insufficient insulin. It is characterised by hypovolaemia (osmotic diuresis) and acidosis (ketone body production); large volumes of fluid are needed in resuscitation, but should be dextrose-free until serum glucose has fallen to below 15mmol/l. There is insulin resistance, and the normal daily requirement will be increased by at least 20%. Insulin therapy causes intracellular uptake of potassium and potassium supplementation is always required. Bicarbonate will only be required in extreme cases with severe systemic acidosis, and rarely with a pH over 7.0. Despite initial high plasma sodium levels, these patients are both salt and water depleted. Initial resuscitation should be with normal saline. Half normal saline may be used with caution.

Reference: Update in Anaesthesia No 11

Question 6

A. true B. true C. false D. true E. false

First described for the assessment of head injury, it is now used for all types of coma. It is most usefully broken down into the components of:

- best motor response (1-6)
- best verbal response (1-5)
- eye opening (1-4)

change over time is a more useful guide to progress than is a single measurement. A score of 2 is not possible as 3 is the lowest score.

Reference: Update in Anaesthesia No 6

Question 7

A. false B. false C. true D. false E. false

Especially if preceded by preoxygenation, signs of hypoxia such as desaturation, bradycardia and ECG changes are late warnings. Capnography is the gold standard but careful auscultation is also helpful in confirming correct placement, although it cannot reliably detect oesophageal placement.

Question 8

A. false B. true C. true D. false E. true

The aetiology of shivering remains unknown but is certainly not due to volatile agents. Peroperative cooling and selective transmission of cold sensation because of a differential neural block are possible contributing factors. A small dose of pethidine may abolish it. Doxapram has also been used. Basal metabolic rate can increase 10-fold and hypoxia is common due to increased oxygen requirements for heat production.

*Reference: Crossley AWA. Anaesthesia 1992;**47**:193*

Question 9

A. false B. false C. false D. true E. false

The technique is an anaesthetic technique and regardless of local practice it should be conducted by suitable qualified anaesthetists with appropriate resuscitation facilities available. Prilocaine 0.5%, without preservative or vasoconstrictor, is the only agent used in contemporary practice, bupivacaine being discarded because of toxicity. The tourniquet should be inflated to twice systolic blood pressure. The quality of postoperative analgesia is disappointing. There is a recognised risk of methaemaglobinaemia with doses of prilocaine in excess of 600mg.

Reference: page 000 this issue

Question 10

A. true B. true C. false D. false E. true

Agents which provoke histamine release should be avoided because of risk of provoking bronchospasm which may be life threatening. These include atracurium, thiopentone and tubocurarine. Ketamine will cause bronchodilation, as do volatile anaesthetic agents despite the respiratory irritant effects of isoflurane when used for the induction of anaesthesia. Non steroidals should be used with caution in patients know to have asthma.

Reference: Update in Anaesthesia No 12

Question 11

A. false B. true C. false D. false E. false

Pulmonary embolism is the most common cause of death in the first ten days post op. Massive PE is associated with cardiorespiratory collapse and a high mortality. Small PE may cause very few symptoms.

Pleuritic chest pain, dyspnoea and haemoptysis are the common features. Cyanosis, tachypnoea and tachycardia may also occur. Hypotension is the more common feature associated with obstruction of the pulmonary circulation. Cannon waves are seen in complete heart block and not pulmonary embolic disease. The common ECG finding include signs of right ventricular strain; right axis deviation, right bundle branch block, T wave inversion in the right chest leads. The pathognomic sign is the S1 Q3 T3 pattern. This is rarely seen.

Ref: Yentis, Hirsch and Smith. Anaesthesia A to Z. Butterworth.

Question 12

A. false B. false C. true D. true E. true

The complications of massive blood transfusion can be classified into those that are related to the volume of blood given and those related to the storage of blood:

Volume related:
- Transfusion reactions
- Transmission of infection
- Alloimmunisation
- Immunological disturbance

Storage related:
- Hyperkalaemia
- Acidosis
- Hypothermia
- Citrate toxicity
- Hypocalcaemia
- Platelet and clotting factor deficiency
- Microaggregate formation and acute lung injury
- Reduced oxygen delivery due to reduce 2,3 DPG levels

Reference: Update in Anaesthesia No 14

Question 13

A. false B. false C. true D. false E. true

Anaphylaxis = An exaggerated response to a substance which the subject has previously been sensitized to, associated with the liberation of histamine. Sensitization may have occurred by exposure to a related substance.Histamine release is the hallmark of anaphylaxis but cannot practically be measured. Instead more durable markers of histamine release should be sought. Tryptase is a neutral protease released during mast cell degranulation. It is

normally undetectable in the serum but levels remain elevated for up to 16 hours following anaphylaxis. N-methyl-histamine, the major URINARY metabolite histamine may also be detectable for prolonged periods.Type 1 hypersensitivity reactions involve IgE (50% of thiopentone reactions)Classical complement mediated activation involves IgG or IgMAlternative complement activation does not involve antibodies

*Reference: McKinnon & Wildsmith. Histaminoid reactions in Anaesthesia. British Journal of Anaesthesia 1995;**74**:217. Update in Anaesthesia No 12*

Question 14

A. false B. true C. true D. true E. true

Anaphylaxis = An exaggerated response to a substance which the subject has previously been sensitized to, associated with the liberation of histamine. Sensitization may have occurred by exposure to a related substance.

- 90% of reactions involve cardiovascular collapse
- 10% involve only cardiovascular collapse as a presenting feature
- 80% get an SVT
- 11% of patients arrest
- 3% get pulmonary oedema
- 50% get bronchospasm
- 3% get only bronchospasm as a presenting feature
- 12% get upper airway oedema

*Reference: McKinnon & Wildsmith. Histaminoid reactions in Anaesthesia. British Journal of Anaesthesia 1995;**74**:217. Update in Anaesthesia No 12*

Question 15

A. true B. false C. false D. false E. false

An ejection systolic murmer may be due to a valvular lesion or may be functional, innocent, and not related to a structural cardiac lesion. Antibiotic cover is recommended for patients with congenital heart disease or acquired valve disease receiving dental or operative treatment. 2D echocardiography will demonstrate calcification or valvular thickening and LVH secondary to aortic stenosis. Doppler echocardiography works out pressures from the velocity of blood within the heart and can be used to determine gradient across the valve. Values over 50mmHg are considered significant, although a poor left ventricle may contract so weakly against a severely stenosed valve that a large gradient is not achieved. Goldmann noted no increase in peroperative mortality with mitral valve disease but a 13% mortality in patients with important aortic stenosis.

Reference: Kaufman L. Anaesthesia Review 10 (Butterworths). Ch1. Also Update in Anaesthesia No 14

Question 16

A. true B. true C. false D. true E. false

Hypokalaemia (potassium less than 3.6mmol/l) may lead to arrythmias, ST depression, T wave inversion and a prominent U wave on the ECG. Hyponatraemia to the extent of 114mmol/l is abnormal. The serum sodium is frequently 5mmol/l less than normal in hospital patients and is a result of sick cell syndrome. Bronchial carcinoma is associated with inappropriate ADH secretion which can cause severe hyponatraemia. Hypercalcaemia over 2.6mmol/l may lead to a shortened QT interval on ECG as well as other cardiac arrythmias and hypertension. The normal plasma CSF glucose is approximately 65% of the blood glucose. A lower CSF glucose than this, as shown, is indicative of bacterial meningitis. The normal plasma albumin is 35-50g/l. Catabolic states such as severe sepsis, trauma, fever and malignancy lead to hypoalbumenaemia.

Reference: Marshall. Clinical Chemistry. J.B. Lippincott Company.

Question 17

A. true B. false C. true D. false E. false

Human malignant hyperthermia is inherited as an autosomal dominant with links to gene loci on chromosomes 17 and 19. Triggering agents include suxamethonium, (which can produce a very rapid onset) halothane, enflurane, isoflurane, desflurane, sevoflurane, methoxyflurane, ether and cyclopropane. The incidence is approximately 1/15,000 anaesthetics. Mannitol is present in bottles of Dantrolene to make the solution isotonic. Miller suggests that 3-4 people will be needed to get a dose of 2gm/kg into solution for an adult. Even in high dose, dantrolene will only produce mild muscle weakness.

Reference: Miller. Anesthesia. Churchill Livingstone. Chapter 31.

Question 18

A. false B. true C. false D. true E. false

Sickle cell disease is commonest in people originating in west and central afrIca and also from around the mediterranean. Sickle cell trait is present in 10% of African Americans in whom 40% of their Hb is as HbS. Sickle cell anaemia is found in 1% of African Americans and their Hb is very predominantly HbS. On desaturation of their Hb the HbS is 50 times less soluble than HbA and tactoids of rigid Hb chains are formed altering the function of the red blood cells. Haemolytic anaemia occurs along with organ damage due to to vascular obstruction in the spleen, kidneys, gut, and brain. Aplastic crises can occur when the bone marrow fails as a result of intercurrent infection or folate defficiency. Exchange transfusion is appropriate prior to major vascular surgery as O_2 carriage is increased and the risk of sickling is decreased. Folate therapy is appropriate as it may help marrow function at a time of additional stress. Esmarch tourniquets have been described as used without problems in some patients although overall the use of tourniquets would be considered contra-indicated.

Reference: Katz J. Anaesthesia and uncommon diseases. Saunders. Sickle cell anaemia. p391-397.

Question 19

A. false B. true C. false D. false E. true

Mitral stenosis is usually the result of rheumatic fever with a distorted and partly fused valve secondarily calcifying. Slow deterioration with dyspnoea, pulmonary oedema, chest pain, palpitations and haemoptysis occurs. Left atrial pressure is chronically raised and pulmonary hypertension occurs. Atrial contraction will contribute 30% of ventricular filling and if atrio-ventricular pacing is needed a long P-R interval will help filling of the ventricle. Cardiac output will usually not be helped by afterload reduction in the setting of a normal blood pressure since the obstruction is at mitral valve level. Pulmonary vascular resistance is a serious problem with right ventricular failure being a risk. If pulmonary vascular resistance increases the right ventricle may further distend and the inter-ventricular septum intrude on left ventricular function. Due to the pulmonary hypertension the pulmonary diastolic pressure will often be considerably above the pulmonary wedge pressure.

Reference: Hensley. The practice of cardiac anaesthesia. Little, Brown. Anaesthetic management for the treatment of valvular heart disease. Also Update in Anaesthesia No 14

Question 20

A. true B. false C. false D. true E. true

In aortic stenosis the normal aortic valve area decreases from $3cm^2$ to less than $1cm^2$. Without increased left ventricular systolic pressures the blood flow across the valve is dependent on the pressure gradient. With compensatory hypertrophy of the left ventricle the aortic valve gradient will increase. However later in the disease as the left ventricle dilates and further fails the left ventricular valve gradient will fall as cardiac output falls. A relatively slower heart rate is important to allow adequate time for left ventricular filling and emptying. The increased impedance to left ventricular emptying is at valve level and so changes in systemic vascular resistance will not signicantly affect left ventricular emptying. However a decrease in systemic vascular resistance may lead to critical reductions in myocardial perfusion. Episodes of myocardial ischaemia should be treated by firstly increasing systemic perfusion pressure. Vasodilators such as nitrates should be used with extreme caution if at all.

Reference: Hensley. The practice of cardiac anaesthesia. Little, Brown. Anaesthetic management for the treatment of valvular heart disease.

Also Update in Anaesthesia No 14

Answers to Self Assessment Questions

Question 1 - Answer

Prolonged late decelerations on the CTG are abnormal and signify probable fetal distress. This is progressive fetal asphyxia that if uncorrected will lead to permanent central nervous system damage or death. Fetal acidosis should be confirmed by performing a fetal scalp pH. This procedure should not, however, delay the institution of intra-uterine fetal resuscitation (IUFR) which should begin immediately. IUFR consists of specific measures aimed to increase the delivery of oxygen to the placenta and the umbilical blood flow, in order to reverse fetal hypoxia and acidosis. The mother should be examined quickly to exclude maternal hypoxia or shock or placental separation (placental abruption) which would require additional specific therapy. The following management should then be instituted immediately:

- Turn the syntocinon off.
- Turn the mother into the left lateral position and if there is no improvement try the right lateral position or the knee chest position in case cord compression is the cause.
- Administer high flow oxygen via a tight fitting Hudson mask with a reservoir bag.
- Infuse 1000mls Hartmann's solution or normal saline rapidly.
- Treat a low blood pressure if it exists. Fluids and vasopressors may be required after epidural analgesia.
- Tocolysis (stopping uterine contractions). Terbutaline 250 micrograms subcutaneously or GTN spray sublingually (2 puffs repeated up to 3 times). [not if placental abruption or antepartum haemorrhage]

If fetal acidosis is confirmed and the fetal heart rate trace does not improve with the above measures a caesarian section will be necessary.

The Physiology of Normal Oxygen Transport to the Fetus

The delivery of oxygen to the organs of the fetus requires oxygen delivery to the maternal side of the placenta (intervillous spaces), placental transfer of oxygen to the fetal blood in the chorionic villi by passive diffusion and an intact fetal circulation.

Oxygen delivery to the placenta. Placental blood flow is determined by the perfusion pressure (arterial pressure - venous pressure) and the resistance to blood flow. Oxygen delivery is defined as placental blood flow multiplied by the arterial oxygen content (haemoglobin concentration multiplied by the arterial oxygen saturation). Branches of the uterine arteries supply the intervillous spaces and the blood returns to the maternal circulation via the uterine veins. The branches of the uterine arteries are maximally dilated during late pregnancy and therefore placental oxygen delivery is close to maximum at this time provided that the mother has a normal haemoglobin concentration, normal oxygen saturations and a normal perfusion pressure.

Placental transfer of oxygen. In the placenta, chorionic villi project into the large 'lakes' of maternal blood in the intervillous spaces and contain fetal capillaries. These chorionic villi are perfused by the umbilical arteries and the blood returns to the fetal circulation via the umbilical vein. The placental transfer of oxygen is a passive process from maternal blood, with a relatively

high PO_2, to the fetal capillaries with a low PO_2. Fetal umbilical venous PO_2 is relatively low (35mmHg) compared to maternal arterial PO_2 (100mmHg when breathing air). This is thought to be due to the structural characteristics of the placenta (it functions as a concurrent exchange system rather than a countercurrent exchange system), poor matching of fetal and maternal blood flow in certain areas of the placenta (analogous to shunt and ventilation/perfusion mismatch in the lung) and because of the high oxygen consumption of the placenta itself.

Fetal circulation. An adequate fetal oxygen delivery is still possible despite the low umbilical venous PO_2 because of a number of factors. The haemoglobin concentration is high (17-19g/dl), the cardiac index high (350mls/m^2/min) and the haemoglobin dissociation curve is shifted to the left compared to the adult because of the presence of haemoglobin F. This means that despite the low PO_2 in the umbilical vein the haemoglobin is 75-80% saturated. The fetal circulation is also designed such that the best oxygenated blood from the umbilical vein is directed via the ductus venosus to the inferior vena cava and via the foramen ovale to the left side of the heart and then to the head and neck of the fetus. The less well oxygenated blood from the superior vena cava enters the right ventricle and then enters the aorta via the ductus arteriosus distal to the left subclavian artery. The less well oxygenated blood is therefore diverted to the trunk and lower body of the fetus.

Effect of uterine contractions on oxygen transport. Active contractions during labour generate intra-uterine pressures of 45-50mmHg which compress the uterine veins and decrease arterial blood flow. This causes a reduction in the PO_2 of the blood in the intervillous spaces and the fetal oxygen saturations decline about 7% to a low point about 90-120sec after the peak of the contraction. Recovery occurs over a similar period of time. When oxygen delivery is borderline contractions may cause a marked fall in fetal oxygenation and fetal bradycardia. This is seen as a late deceleration on the CTG. When oxygen delivery is severely impaired, oxygenation fails to recover between contractions and a sustained bradycardia results.

Pathological Conditions Causing an Inadequate Oxygen Delivery to the Fetus

- **Maternal hypoxia**
- **Maternal hypovolaemia / hypotension**
- **Aortocaval compression**. The pregnant uterus may compress the inferior vena cava and aorta within the abdomen. This is usually worst when the mother is lying on her back but can occur in other positions to. Caval compression decreases venous return and cardiac output and may result in maternal symptoms of hypotension. Isolated aortic compression does not produce maternal symptoms but will also result in a decrease in fetal oxygen delivery.
- **Uterine hyperstimulation**. This is defined as a contraction frequency of more than one in every 2 minutes and does not allow recovery of fetal oxygenation between contractions. As already explained a normal contraction frequency can cause distress to a fetus without physiological reserve.
- **Placental separation/abruption**
- **Pre -eclampsia**
- **Umbilical cord compression**. This is most obvious when the cord prolapses into the vagina but it may also be compressed in the uterus. If compression is severe enough to cause fetal hypoxia the bradycardia follows contractions but the timing is not constant (variable decelerations).
- **Fetal haemorrhage**
- **Regional analgesia**. Sympathetic blockade will worsen any tendency to supine hypotension. Some of the changes in fetal heart rate pattern seen after regional analgesia may be due to an increase in uterine activity.

*[Ref: Thurlow JA and Kinsella SM. Intrauterine resuscitation: active management of fetal distress. International journal of Obstetric Anaesthesia (2002)**11**,105-116]*

Question 2 - Answer

Left lower lobe collapse (left diaphragm not seen and double shadow along left heart border). Initial treatment would include humidified oxygen and physiotherapy to re-expand the lung. If this was not successful a bronchoscopy could be performed. Antibiotics should be prescribed.

Question 3 - Answer

1) Chronic subdural haematoma
1) Acute extradural haematoma
2) Subarachnoid haemmorhage

INTRAVENOUS REGIONAL ANAESTHESIA - BIER'S BLOCK

Dr Natasha Clark, Royal Devon & Exeter Healthcare NHS Trust, Barrack Road, Exeter, Devon EX2 5DW.

Intravenous regional anaesthesia (IRVA) was first described by Augustus Bier in 1908; his technique was repopularised by Holmes in 1963. The administration of intravenous local anaesthetic in an isolated limb by means of an ischaemic cuff is a simple and effective technique, with a low incidence of failure and high degree of safety.

Clinical Application

IVRA is ideally suited to operations of the distal arm or leg (i.e. below the elbow or knee), such as reduction of a radial or ulna fracture. IVRA is useful for only short surgical procedures; performed in 40 minutes or less (the length of operating time is limited by tourniquet pain, which usually develops after 40 to 60 minutes.

IVRA is often a safer option than general anaesthesia, particularly if the patient is elderly, or has cardiovascular or respiratory disease. Of particular importance in hypertensive patients, the tourniquet cuff used must be sealed and inflated to the correct pressure (see below).

Contraindications to IVRA

- Severe Raynaud's Disease (intermittent arteriolar vasospasm of the distal limbs after cold or emotional stimuli).
- Sickle Cell Disease (IVRA is relatively contraindicated, unless meticulous exsanguination of the limb takes place prior to cuff inflation).
- Crush injury to the limb, IVRA may provoke further tissue damage secondary to hypoxia.
- Age - young children are generally not amenable to IVRA alone, however in combination with sedation and additional analgesia it can be used successfully.
- Patients should be starved, as there may be a possibility of conversion to a general anaesthetic, alternatively the patient may require sedation in addition to IVRA to improve co-operation.

Equipment Required For IVRA

- A single or double tourniquet cuff that that has been checked to ensure that it **does not leak**, and can be inflated 50 to 100mmHg above the patient's systolic blood pressure.
- Two intravenous cannulae, one for venous cannulation distal to the tourniquet and one for cannulation in the opposite arm to allow access to the circulation if required in the event of complications.
- Full resuscitation equipment and ECG monitoring at all times including immediately after tourniquet deflation.

Drugs Required For IVRA

Prilocaine is the local anaesthetic agent of preference because of its high margin of safety (it has a high therapeutic index). 40ml of 0.5% prilocaine is recommended, although larger volumes will be required for lower limb IVRA (60ml). The maximum dose is 400mg for a 70kg adult (approximately 6mg/kg) which equates to 80ml of 0.5% solution.

Lignocaine is a useful alternative agent. On average 40ml 0.5% lignocaine is required. The maximum dose is 250mg for a 70kg adult (approximately 3mg/kg), which equates to 50ml of a 0.5% solution. Only plain solutions of prilocaine or lignocaine should be used (without adrenaline).

Bupivacaine is unsuitable for IVRA and should never be used due to its cardiotoxic profile (leading to ventricular arrhythmias and death).

IVRA Technique (Figure 1)

- Attach patient to ECG monitor and measure the blood pressure.
- Insert a cannula as distal as possible in the limb to be operated upon.
- Insert a second cannula into the opposite arm for intravenous access (in case of emergency).
- Exsanguinate the limb either with an Esmarch rubber bandage of by simply elevating the limb for several minutes, with brachial / popliteal artery occlusion.

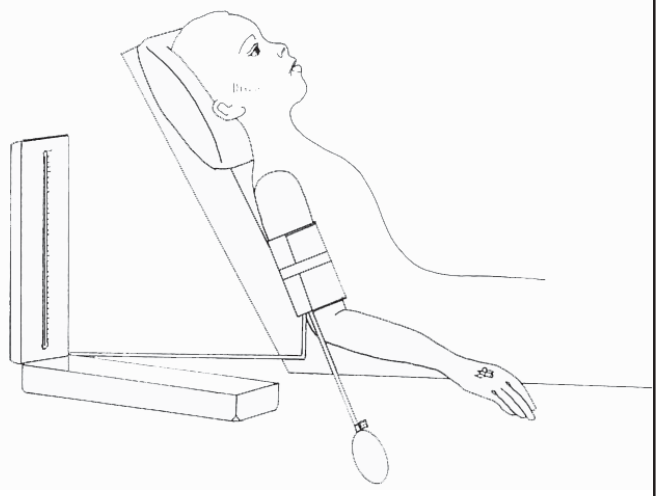


Figure 1: Biers Block

- Protect the upper part of the limb with wadding before placing and inflating the tourniquet to 50 - 100mmHg above their systolic blood pressure (typically 200 to 250mmHg). Check for an absent distal pulse on the limb (radial or dorsalis pedis). During the operation the tourniquet should be observed continuously to check for unintentional slow deflation.

- Inject the local anaesthetic solution slowly via the IV cannula and inform the patient that the limb will feel a little strange and become mottled in appearance. An assistant gripping the forearm during local anaesthetic injection will ensure the most of the anaesthetic solution is retained distally.

- Surgical preparation and draping may proceed about 5 minutes after local anaesthetic injection.

- The tourniquet must remain inflated for a minimum of 20 minutes from the time of local anaesthetic injection.

- Surgical procedures lasting longer than 40 minutes may result in the patient complaining of tourniquet pain, this can be reduced by the use of a double cuffed tourniquet - initially the uppermost cuff is inflated and this can be switched to the lower cuff. The addition of 150mcg clonidine to the local anaesthetic solution may reduce tourniquet discomfort and thus improve conditions. Alternatively, intravenous analgesia such as fentanyl, or ketorolac can be administered (via the emergency IV cannula in the other hand).

- At the end of the procedure the IVRA cannula is removed and the cuff deflated - close observation of the patient is crucial at this point, as this may result in systemic release of local anaesthetic. The patient's blood pressure should be measured and ECG monitoring continued for at least 10 minutes following cuff deflation.

Complications

IVRA is generally a safe technique. The most important complication to recognise is a leaking or accidentally deflated tourniquet cuff - this will result in a large volume of local anaesthetic being rapidly introduced into the circulation. The patient may develop dizziness, nausea, vomiting, tinnitus, perioral tingling, muscle twitching, loss of consciousness, and convulsions. Avoidable deaths have occurred.

Management of Systemic Toxicity of Local Anaesthetics

- **Airway** - Maintain the patient's airway, administer 100% oxygen and call for help. Turn the patient onto their side; lower their head if possible to prevent aspiration.
- **Breathing** - start ventilation if breathing inadequate. Intubate if indicated.
- **Circulation** - pulse check. If in cardiac arrest start CPR. Assistant to start monitoring ECG, pulse oximetry, and blood pressure.
- **Convulsions** - IV 5mg diazepam or 50mg - 200mg thiopentone. Muscle relaxation if required.
- **Hypotension** - IV ephedrine 3-6mg increments, elevate legs, IV fluid bolus

Summary

IVRA is a simple and effective regional anaesthetic technique to perform, provided that the cuff is checked, and its' pressure monitored.

Resuscitation and monitoring equipment should be readily available when conducting IVRA.

References

1. Gentili M Bonnet F Bernard JM. Adding clonidine to lidocaine for IVRA prevents tourniquet pain. *Anesthesia Analgesia* 1999;**88**:1327-30.

2. Haasio J Hippala S Rosenberg PH. Intravenous regional anaesthesia of the arm. *Anaesthesia* 1989;**44**:19 -21.

LETTER TO THE EDITOR

Dear Sir,
Recently we have been following the procedure that after spinal anaesthesia we position the patient with a pillow to prevent post-operative headache. Why is this useful?

Staff nurse, Bhutan

Comment by Dr Michael Dobson
There is a tradition that patients should lie flat after a spinal anaesthetic to prevent headache. Spinal headaches (after spinal anaesthesia and lumbar puncture) are caused by CSF leaking out of the hole in the meninges caused by the spinal needle. The bigger the leak, the worse the headache. If a headache occurs it is often relieved by lying down flat, but there is no evidence to suggest that lying down actually prevents the headache.

In general, the bigger the hole in the meninges, the worse the headache. I use only 27 or 25 gauge needles for spinals - with these, the chance of a headache is only 1%, and it makes no difference whether the patient lies flat or not. So the message is, if you use a careful technique and use a fine needle, lying flat is not necessary and patients can sit up after the block has worn off.

ANAESTHESIA FOR THE ELDERLY PATIENT

Dr Fiona Kelly, Bristol Royal Infirmary, Bristol, and Dr Rose Mulder, Cape Town, South Africa.

- Introduction
- Age-related physiological changes
- Alterations in organ function
- Preoperative preparation
- Intraoperative management
- General or regional anaesthesia?
- Postoperative care
- Further reading

Introduction

Increasing numbers of elderly patients are presenting for surgery due to longer life expectancy. The incidence of peri-operative complications is much higher in these patients due to reduced functional reserve and a high incidence of co-morbidity, but these complications can be minimised by careful preoperative assessment, a meticulous anaesthetic technique and good postoperative care.

Age-Related Physiological Changes

Ageing is a process where progressive cell loss occurs, at a variable rate, in individual patients and their organ systems.

The concept of "functional reserve" is derived from the difference between the basal level of organ function at rest and the maximum level of organ function that can be achieved in response to increased demand, for example during exercise or in response to surgical stress. Functional reserve is often reduced in elderly patients, and is thought to be a major factor in the increased morbidity and mortality of the elderly population. However, decreased functional reserve may be difficult to detect. Some patients are limited by lack of mobility and as a result do not exert themselves as much. These patients rarely admit to breathlessness or angina, yet they may have significant underlying and undetected ischaemic cardiac disease.

Alterations In Organ Function

Almost all age-related changes in organ systems are relevant to the anaesthetist. However, reduction in cardiovascular, pulmonary, renal and central nervous system function may be the most important determinants of outcome from surgical procedures under general or regional anaesthesia.

Cardiovascular system

Ischaemic heart disease is common in affluent societies. Smoking, hypercholesterolaemia, hypertension, type 2 diabetes mellitus and obesity all contribute to the development of atherosclerosis. The result is a less compliant arterial tree, increased systemic vascular resistance and systemic hypertension. The net effects on the heart are concentric left ventricular hypertrophy, reduced ventricular compliance and contractility, and eventually reduced cardiac output.

In contrast, valvular heart disease secondary to rheumatic fever is more commonly seen in developing countries. Over 50% of patients will have mitral valve disease. Aortic lesions are less common.

The reduced cardiac output in heart disease compromises blood flow to the kidneys and brain. Autoregulation of blood flow to these organs is impaired in the elderly, and therefore both the kidneys and brain are prone to peri-operative ischaemia.

The physiological response to cardiovascular stressors (such as hypovolaemia) may be blunted due to reduced baroreceptor sensitivity and autonomic function. This lack of compensation may be significant if the patient is taking medication such as beta-blockers or ACE inhibitors. A normal response to exercise in young patients is an increased heart rate and ejection fraction. This response is blunted in elderly patients, due to decreased reactivity of (βreceptors, and as a result the ejection fraction may even fall. Maximum cardiac output and hence functional cardiac reserve decreases as age increases.

Atrial fibrillation (AF) in the elderly population is common, probably due to a progressive loss of atrial pacemaker cells with ageing. A 70 year old adult has only 10% of the atrial pacemaker cells that an adolescent has. The fast ventricular rate in AF leads to poor diastolic filling and reduced cardiac output: both are poorly tolerated in an elderly patient. Preoperatively, a patient in AF should ideally be cardioverted, but failing this the ventricular rate should be controlled to <100/minute.

Respiratory system

Pulmonary elasticity, lung and chest wall compliance, total lung capacity (TLC), forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), vital capacity (VC) and inspiratory reserve volume (IRV) are all reduced, with an increase in the residual volume. Although functional residual capacity (FRC) is unchanged, closing capacity rises progressively with age, and may become greater than the FRC - this occurs in the supine position at 44 years of age and in the upright position at 66 years. The end result of these changes is airways collapse, VQ mismatch and hypoxaemia, even during tidal volume breaths. The small airways and alveoli therefore have to be reopened at each inspiration, leading to increased work of breathing and possible difficulties weaning from ventilation. The efficiency of gas exchange is reduced, and as a result PaO_2 decreases with age (PaO_2 =13.3-age/30 kPa, or PaO_2 =100-age/4mmHg) although $PaCO_2$ remains constant.

Atelectasis, pulmonary embolism and chest infections are all more common in elderly patients, particularly following abdominal or thoracic surgery. Ineffective mucociliary activity exacerbated by smoking increases the risk of complications. Early mobilisation and good analgesia following abdominal surgery help reduce lung atelectasis and collapse.

Renal system

Glomerular filtration is reduced. Muscle bulk decreases with age resulting in reduced creatinine production, hence even a modest rise in serum creatinine may represent significant renal impairment.

Tubular function is also impaired, with reduced renal concentrating ability and reduced free water clearance. Clearance of renally excreted drugs is reduced, and fluid balance is more critical as responses to both fluid loading and dehydration are impaired. Renal function may deteriorate rapidly in hypovolaemic patients, particularly those taking NSAIDs (non steroidal anti-inflammatory drugs) or ACE inhibitors such as captopril. Close monitoring of hourly urine output after major surgery should be routine.

Nervous system

An age-related decline in central nervous system (CNS) function is common, the causes of which include cerebrovascular disease, changes in hormone levels, neuronal damage induced by oxidative stress as well as a generalised progressive loss of cells. As a result, confusion is more common, both pre and post-operatively.

Cognitive impairment increases with ageing, and dementia may affect up to 20% of patients over 80 years of age. However, it is important that dementia is only diagnosed after formal testing, ideally by specialists in geriatric psychology.

Blindness affects nearly 30% of the elderly, largely due to cataracts and glaucoma, and may make understanding written material such as consent forms and visual analogue pain scales very difficult. Deafness is more common, and may be severe in about 35% of elderly patients.

Autonomic dysfunction is also more prevalent in the elderly population, and may result in labile blood pressure and arrhythmias perioperatively. The baroreceptor reflex may be attenuated, leading to postural hypotension and a drop in blood pressure during anaesthesia, particularly during induction in a relatively hypovolaemic patient. Impaired temperature regulation and delayed gastric emptying may also occur, the latter predisposing the patient to aspiration. A rapid sequence induction should therefore be performed in such cases.

Endocrine

The incidence of diabetes is increased in the elderly, and may be seen in up to 25% of patients aged over 80 years. Diabetics frequently have cardiovascular, renal, neurological and visual impairment, and require control of blood glucose levels during the perioperative period. (*See Update in Anaesthesia issue 10*)

Pharmacology

Pharmacokinetics may be altered, with reduced hepatic and renal blood flow and a reduction in total body water. Plasma proteins are often reduced, resulting in reduced protein binding of drugs and metabolites, thereby increasing free drug levels and possible toxic effects.

Pharmacodynamics may also be altered, with increased sensitivity to many agents, especially CNS depressants. Minimum alveolar concentration (MAC) decreases steadily with age by 4-5% per decade after 40 years - for example the MAC of isoflurane is approximately 0.92 at 80 years of age.

It may be difficult to ascertain exactly which medications are being taken, especially when patients are admitted as an emergency. Patients may be confused as to what drug/drugs they are taking, compliance may be poor, or medication may have been inadvertently stopped. It may be necessary to confirm exact details of current medication with a patient's relatives or family doctor. Long-term medication should usually be continued throughout the hospital stay.

Nutrition

Malnutrition is common in the elderly, and is associated with increased morbidity and mortality. Trials of nutritional supplementation reduce the length of hospital stay and postoperative complications. Consider oral protein supplementation in those with significant malnutrition.

Musculoskeletal

Degenerative diseases of all types affect the elderly, and arthritis is almost universal. This may limit exercise tolerance and makes it difficult to assess fitness. Osteoporosis and ligament laxity makes epidurals and spinals technically difficult; in addition, the patient is prone to fractures or dislocation of joints (including the cervical spine) while anaesthetised. Care should be taken with patient movement and intra-operative positioning. Vulnerable pressure points should be well padded.

PREOPERATIVE PREPARATION

Assessment

- A full history and thorough clinical assessment is required - significant cardiac, respiratory and renal disease may not have been previously detected. An ECG is required for all patients. A chest X-ray should be arranged for patients with known malignancy or possible tuberculosis, and for anyone with symptomatic cardiovascular or respiratory disease who has not had a recent chest X-ray. Note the level of cognitive function and the patient's social circumstances: these may determine both the perioperative prognosis and plans for the patient's rehabilitation postoperatively.

- In patients who have sustained a fracture, actively look for an underlying medical cause for a fall, such as arrhythmias, myocardial infarction, transient ischaemic attack (TIA), cerebral vascular event (CVE), pulmonary embolus, gastrointestinal bleed.

- Assessment of exercise tolerance and functional ability is important. The baseline functioning of the patient should be well documented. If a decreased functional reserve is detected, a high-care or intensive care facility may be appropriate post-operatively.

- A full explanation of the perioperative period should be given (details such as catheters, nasogatric tubes, CVP lines are important so the patient is expecting these when awakening). The patient should be consented for anaesthesia. If the patient will be on a different ward postoperatively, a preoperative visit may reduce confusion after the operation.

- The American Society of Anaesthesiologists (ASA) score should be recorded - it remains a good predictor of outcome in the elderly.

Resuscitation/optimisation pre-operatively

Dehydration is common (note large fluid losses are associated with routine bowel preparation, and it is common to lose 50-1000mls of blood with a femoral neck fracture, especially with an extracapsular or trochanteric fracture.). Consider prescribing preoperative fluids if not already done.

One issue that is currently being debated in the anaesthetic press is whether patients, and especially elderly patients with ischaemic heart disease, may benefit from preoptimisation. This describes the enhancement of oxygen delivery to the tissues during the perioperative period, by using fluid therapy, oxygen and possibly inotropic agents. One high profile study in the BMJ showed a significant reduction in mortality following major surgery by using fluid and inotropic therapy along with invasive haemodynamic monitoring, but as yet this has not become routine practice in the UK.

Consider day case surgery

The advantages of this include less confusion, earlier mobilisation and less nosocomial infections. However, day case surgery does need meticulous planning and preoperative assessment, including a detailed social appraisal as to the level of home support and care available.

Decision to operate.

Extensive surgery may be futile in certain patients. Sometimes the best decision is not to operate and this should be made at consultant level, ideally in consultation with the patient and other members of the family.

PERIOPERATIVE CARE

In general the full range of anaesthetic drugs and techniques used for young, fit adults may be used in elderly patients, within the limitations of their physiology. Modification of the techniques, and particularly drug doses, may be required.

Induction of anaesthesia

Arm-brain circulation time is increased, and induction agent dose requirements are drastically reduced. Titrate drugs slowly against effect, and inject into a running intravenous infusion. Thiopentone or propofol are both useful but should be given slowly to avoid overdose. An induction dose of propofol may result in hypotension and require a vasopressor. Avoid ketamine in the presence of cardiac disease as the tachycardia and hypertension that may result can increase myocardial oxygen consumption and precipitate ischaemia. However, bear in mind that ketamine's hallucinogenic effects are not as marked in the elderly, and that it remains a very safe and effective analgesic, anaesthetic and sedative.

Maintenance of anaesthesia

Maintenance of anaesthesia with inhalational agents is a suitable technique for elderly patients, as the depth of anaesthesia can be rapidly changed and inhalational agents are minimally metabolised. Isoflurane is maybe the most suitable, as it is relatively cardiovascularly stable, has a short onset and offset time and only 0.2% of an administered dose is metabolised. Halothane has the advantage of being non-irritant to the upper airway and respiratory tract, although it sensitises the myocardium to catecholamines and so may predispose to tachyarrhythmias. Ether has been used successfully for many years, and in elderly patients is best given in low concentrations with supported ventilation. This allows the patient to wake up more quickly than prolonged deep ether anaesthesia.

Temperature

Maintenance of body temperature pre-, intra- and postoperatively is essential. Elderly patients have a reduced basal metabolic rate (BMR) and are susceptible to heat loss as a result of impaired thermoregulation. Shivering may increase oxygen demand significantly and so should be avoided whenever possible. Conservation of heat by wrapping a patient up (including the head if possible), using fluid warmers and active warm air systems if available, and by operating in a warm ambient environment all help maintain body temperature and aid recovery.

Fluid management

Careful peri-operative fluid balance is mandatory in the elderly. Always consider measuring the CVP with large fluid shifts. Patients are more often underfilled than overloaded, although care should be taken to avoid fluid overload: excess fluids in an elderly patient, especially in the presence of renal failure, can cause pulmonary oedema. Conversely, dehydration, which can be difficult to assess in the elderly, can precipitate renal failure. Regular review of fluid therapy is essential after major surgery.

Pressure areas

Most pressure sores develop within the first 24 hours after surgery, and are more common in patients who have undergone long procedures, and those who have been exposed to periods of hypotension and poor tissue perfusion. Pressure sores should be avoided as they prolong hospital stay, delay rehabilitation and may cause sepsis. Suitable measures to prevent sores should be taken in both the operating theatre and recovery areas.

General or regional anaesthesia?

Regional anaesthesia may have some advantages over general anaesthesia, including less thromboembolic events, confusion and respiratory problems post-operatively. Limb and plexus anaesthesia are ideal for peripheral surgery. Hernias and cataracts are widely performed under local anaesthesia.

Hypotension is more commonly seen in elderly patients undergoing spinal/epidural anaesthesia due to impaired autonomic function and reduced compliance of the arterial tree. In patients with severe cardiovascular disease who require tight control of their blood pressure, general anaesthesia may be better. The Cochrane Review of anaesthesia for hip fracture surgery looked at 17 trials (involving a total of over 2800 patients) comparing regional and general anaesthesia. It concluded that regional anaesthesia may reduce mortality at one month, but that regional and general anaesthesia appear to produce comparable results for longer term mortality.

POSTOPERATIVE CARE

Oxygen therapy

It is good practice to prescribe post-operative oxygen therapy for all elderly patients, and especially following abdominal or thoracic surgery, in the presence of cardiovascular or respiratory disease, in situations where there has been significant blood loss, or when opioid analgesia has been prescribed. Nasal cannulae are often better tolerated than facemasks.

High dependency care

If high dependency care or intensive care facilities are available, these may improve the long-term outcome of elderly patients, especially those undergoing urgent or emergency surgery.

Analgesia

Consider prescribing a regular simple analgesic such as paracetamol, and use NSAID's with caution; the complications of NSAIDs, including renal impairment and peptic ulceration, are more prevalent in older patients.

Intramuscular and subcutaneous opioids may be unreliably absorbed due to variable tissue perfusion, and an elderly confused patient may have difficulty using a PCA. Regional techniques or an iv opioid infusion (with appropriate close supervision) may be the most appropriate method of pain relief.

Involve an acute pain team whenever possible and consider using pain assessment charts: these should include regular pain and sedation scoring, using recognised non-verbal scoring systems if possible. The use of such pain assessment charts has been shown to improve pain management and to reduce the complications related to post-operative analgesia.

Fluid management

Meticulous fluid management continues to be extremely important during the post-operative phase. Fluid balance charts should be utilised and carefully interpreted: failure to do so has been shown to be a major contributing factor in post-operative morbidity and mortality.

Other considerations

- Frequent and regular review of the patient should be routine.
- Early and frequent physiotherapy and mobilisation facilitate post-operative recovery and have been shown to reduce hospital stay significantly.
- Consider deep vein thrombosis (DVT) prophylaxis: elderly patients are a high-risk group, especially those with a fractured neck of femur or those who have been bed bound for some days.
- Regular review looking for postoperative complications. Common complications include infection (especially wound, chest, urine), DVT and pulmonary embolus. Confusion may also be seen, and may be due to sepsis, dehydration, overhydration, abnormal urea and electrolyte levels, hypoxia, alcohol/drug withdrawal or pre-existing cognitive impairment/dementia.
- Parenteral or enteral nutrition should be continued from the pre-operative period, or instigated early after surgery to facilitate healing and aid recovery.
- Rehabilitation using a multidisciplinary team is strongly recommended.

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PERIOPERATIVE HEADACHE

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Headache is common in the perioperative period (up to 54% patients). Predisposing factors include a history of regular headache and high caffeine intake. Preoperative headache is a strong predictor for postoperative headache. Headache is reported more frequently by females.

General points

- History is more important than examination. Neurological signs warrant thorough investigation.
- Investigations must be tailored to the presumed cause
- Specific treatment must be directed to correct the underlying cause.
- First line should include reassurance and simple analgesia where appropriate.

Causes of headache specific to perioperative period

- **Hypoxia/Hypercapnia**. Both induce cerebral vasodilatation. Hypoventilation is commonly the cause of opioid related headache.

- **Dehydration/prolonged preoperative fast/caffeine withdrawal**. Dehydration causes traction on venous sinuses; hypoglycaemia leads to cerebral vasodilatation; caffeine normally induces vasoconstriction, acute withdrawal in those with high daily intake will cause rebound vasodilatation and headache. Prophylactic caffeine in such patients may reduce incidence of headache or simply try a cup of coffee in the postoperative period if not fasting.

- **Hypertension/Pre-eclampsia**. Cerebral vaso-dilatation and oedema in severe cases.

- **Pharmacological**. Nitrates and other anti-hypertensives frequently cause headache. Exogenous vasopressors (including ergotamine) can cause severe headache. Acute alcohol withdrawal (hangover) is common in trauma cases. Withdrawal of regularly taken analgesics may cause headache. Combination 'over the counter' analgesics (often containing ergotamine or caffeine and not disclosed) are the most frequent problem, although headache has been reported on cessation of other analgesics. Headache occurs more frequently in women and typically worsens on withdrawal of analgesics, for example whilst using alternative analgesia such as an epidural. Amitriptyline (25mg bd) and reassurance may be effective - concurrent depression is common. Steroids, 5HT antagonists such as ondansetron, metronidazole, acetazolamide and muscle relaxants also may precipitate headache.

- **Sepsis**. Any cause of fever leads to systemic vasodilatation.

- **Meningitis**. Increased vigilance after ENT, neurosurgical and maxillofacial surgery. Neck stiffness, altered conscious level or photophobia suggestive. Rash less likely than in community.

- **Traumatic**. Approximately one third of patients, after significant head injury, will develop persisting or recurring headache with no structural abnormality. Exclude serious causes with examination and definitive imaging.

- **Raised Intracranial Pressure**. Direct stimulation of pain-sensitive structures (meninges, vessels) by traction, distension or dilatation. Pain worse on lying, coughing and straining. Highly significant if headache wakes patient. Nausea/vomiting suggestive of increased ICP. Papill-oedema and loss of retinal venous pulsation are useful signs, although not in acute rises of ICP. Consider extradural collection in acute trauma; subdural in older trauma (especially elderly, alcoholics and patients taking anticoagulants); cerebral abscess post ENT procedures (swinging fever, decreased conscious level); undiagnosed brain primary or metastatic tumour (may be slow to wake post GA).

Post Dural Puncture Headache (*see Update in Anaesthesia - No. 13*)

This occurs either after spinal anaesthesia or following an unintended lumbar puncture during epidural anaesthesia. . Young patients are especially at risk. Postural variation (headache usually diminishes significantly on lying flat) is crucial to the diagnosis. May appear hours or days post dural puncture. Typically bifrontal, dull pain associated with nausea and photophobia. Neck stiffness can occur but no fever present.

The headache is thought to originate from traction on the dura because of leakage of CSF.

Initial therapy consists of reassurance, hydration (if necessary by the intravenous route), simple analgesics, bed rest and caffeine either by tablets or encouraging coffee intake. Many will resolve over the next 24-48 hours.

If the headache persists over 48 hrs or is incapacitating then an epidural blood patch can be performed after discussion with the patient. This is effective in treating 90% of cases. It should be performed by 2 anaesthetists aseptically

Causes of headache exacerbated in perioperative period

- **Tension Headache**. The most frequent cause. Common in stress and anxiety (increased perioperatively). Described as a "tight band". Usually worsens over the day. Previous attacks common. If simple measures fail, try anxiolytics or antidepressants.

- **Migraine**. Classically a visual aura (zigzag lines/flashing lights highly predictive) followed by unilateral throbbing headache. Nausea/light intolerance may accompany. Patient takes to bed. Focal signs may be present. Usually prior attacks or positive family history. 5HT1 agonists are specific therapy e.g. sumatriptan (Imigran(r)) 50mg PO, 6mg S/C, 20mg intranasally. Avoid in ischaemic heart disease, uncontrolled hypertension or

pregnancy. Take as soon after start of attack as possible. Rapid relief indicates correct diagnosis. Often paracetamol or metoclopramide suffice.

- **Cluster Headache**. Consider in middle-aged men who smoke. Severe unilateral peri-orbital pain often starting at night, lasting 20-120min. Reassure and seek expert opinion.

- **Cranial Arteritis**. Consider in all over 55 years especially if associated visual symptoms/raised ESR. Ask about jaw claudication. Early treatment with steroids important. Biopsy can be taken up to 48hr post dose.

- **Cervicogenic Headache**. Typically unilateral, posterior headache that can be precipitated mechanically. Often coexists with cervical spondylosis. Physiotherapy is the best treatment.

- **Subarachnoid Haemorrhage**. Sudden onset occipital headache with or without collapse, vomiting, altered conscious level or focal signs. CT scan and liase with neurosurgeons. Can occur anytime.

Further reading

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POSITIONING ON THE OPERATING TABLE

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Positioning patients is an important daily routine for anaesthetists to facilitate surgical access for a number of procedures. Different positions produce a range of physiological stresses. Particular care is needed for positioning anaesthetised patients to avoid passive movements that would not normally be tolerated. Nerve damage and pressure necrosis commonly result from poor positioning, the incidence is increased by hypotension and hypothermia.

Tourniquets can cause nerve damage if they are applied over a nerve trunk therefore the inflation pressure and the time of application should always be monitored. Diabetics, patients with arterial disease, the elderly and those with neurological deficits are also at particular risk.

Patients with rheumatoid arthritis may suffer from cervical spine instability at the atlanto-occipital level and it is important that their range of neck movement be assessed preoperatively. They should then be comfortably positioned prior to induction and this position maintained once anaesthetised. Sandbags may be employed.

Supine - "On the back"

The most common position. The arms should be carefully secured either next to the patient's body, flexed across the chest or out on armboards. Acute flexion at the elbow may cause ulnar nerve damage due to trapping where it enters the cubital tunnel. The brachial plexus is a relatively fixed structure and therefore susceptible to traction injury. To avoid "stretch" on the plexus, pronate the forearms when the arms are extended by the patient's sides. When both arms are abducted on boards, prevent over-abduction and hyperextension and keep the head facing forward. When one arm is abducted, the head should be turned towards that side, again to prevent traction on the brachial plexus (Figure 1). Legs should lie flat and uncrossed. A soft pad raising the heels from the table avoids pressure necrosis. Other sites susceptible to pressure damage are the sacrum and occiput and postoperative alopecia (hair loss) has been reported after long operations where hypotensive techniques have been employed. The patient's eyelids should be carefully closed and taped to avoid corneal abrasion and dehydration. Direct pressure on the eye should be avoided as central retinal artery occlusion may occur. Ensure that no part of the breathing circuit, or other equipment, is pressing on the patient's face.

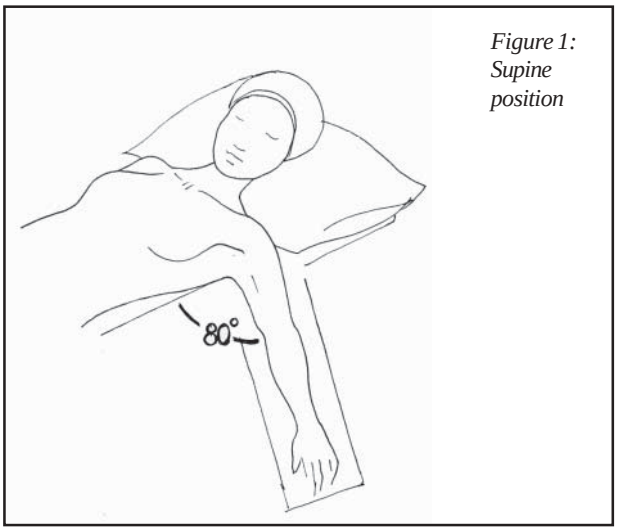

Figure 1: Supine position

Trendelenberg - "Head down"

Supine with head down tilt. This position is used in laparoscopic and varicose vein surgery.

Physiological effects of this position include:

- increased venous return
- raised intracranial and intraocular pressure. Cerebral oedema and retinal detachment may occur if Trendelenberg is prolonged and steep. It is therefore important to avoid this position in a patient with potentially raised ICP.
- lung compliance and functional residual capacity (FRC) are decreased with increased V/Q mismatch, especially in obese patients (IPPV may be preferable to SV)
- increased intragastric pressure may result in reflux of gastric contents
- venous stagnation with resulting cyanosis in the face and neck of plethoric patients

Reverse Trendelenberg - "Head up"

Supine with head up tilt. Reduced venous return in this position may lead to a fall in cardiac output and arterial pressure. As baroreceptor activity is reduced under anaesthesia a vasopressor may be needed. Blood pressure readings should be interpreted in the context of relative positions of the blood pressure cuff and the level of the brain above it. Functional residual capacity (FRC) is improved.

Lawn chair position (Figure 2)

Backache following anaesthesia is common and may occur from stresses on the interlumbar and lumbosacral ligaments, when the convexity of the lumbar spine is lost in the "lying to attention" position. The lawn chair position was developed to reduce this backstrain. The operating table is modified so that the patient lies slightly head up with hips and knees partially flexed. It is particularly useful for patients undergoing awake local anaesthetic procedures.

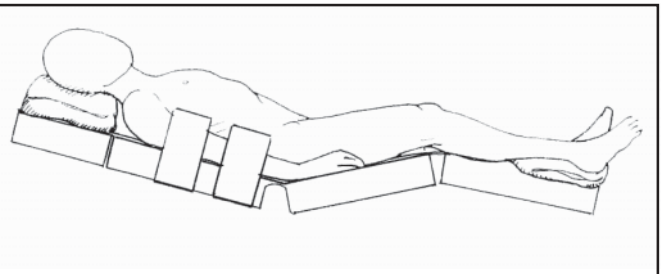

Figure 2:

Prone - "Face down"

Used for spinal surgery, ligation of the short saphenous vein and some ankle operations. Intubation is normally required (although for short procedures a Laryngeal mask airway is sometimes used). A well-secured, armoured endotracheal tube is most suitable. Adequate eye protection and padding is vital because pressure on the eye can cause retinal artery occlusion and blindness.

A sufficient number of persons are required to turn the patient prone - the larger the patient the greater the number of assistants required. Usually 4 people will suffice: the anaesthetist to control the head, and 2-3 assistants to support the torso and arms, buttocks and legs respectively. The patient may be turned prone after transfer to the operating table or alternatively, turned in the process of the transfer. The head is positioned to one side or face down on a piece of hollow foam or headrest. Pressure should be limited to the forehead. Avoid any pressure on the eyes and ensure the endotracheal tube is secure. The arms are positioned fully adducted so they lie by the patient's side or are abducted and flexed at the elbow so they lie alongside the head. Avoid undue pressure in the axillae as axillary nerve or brachial plexus neuropraxia may occur from overstretching (Figure 3).

Pressure points tend to be the head/face, anterior superior iliac spines, knees and feet which should all be well padded. Lung compliance is reduced due to decreased chest wall and diaphragmatic excursion. To aid compliance, a "Montreal" mattress (a rectangular mattress with a hole in its centre) may be used to prevent the abdominal contents forcing the diaphragm upwards. Alternatively, pillows should be placed under the iliac crests and chest, leaving the abdomen unhindered. This also prevents undue movement of the back and allows for efficient drainage from the epidural veins by reducing intrathoracic and intra-abdominal pressure. When using frames that support the anterior superior iliac spines, the lateral cutaneous nerve of the thigh may be compressed and stretched. The "Tarlov knee-chest position" (prone seated position) is a reliable position for lumbar surgery. The buttocks are supported on a "seat" and the table tilted upwards. This position rarely causes any damage other than an erythematous reaction on the skin of the knees.

Figure 3:

Lithotomy - "Legs up"

Used for gynaecological and anal surgery. Both legs should be moved together to avoid strain on the pelvic ligaments and the knees should be positioned outside any metal supports. Avoid placing arms at the side as metal contact with the lithotomy pole may occur and trapping of digits in the lower section of the table is possible.

Potential problems include:

- common peroneal nerve damage due to compression between the head of the fibula and lithotomy pole if knee positioned inside the metal support
- saphenous nerve compression between lithotomy pole and medial tibial condyle
- autotranfusion from the leg vessels will increase preload. The effect on cardiac output will depend on the patient's volume status
- vital capacity is decreased
- risk of aspiration is increased therefore anaesthesia should never be induced in this position. Further, if reflux or vomiting occurs during induction, turning the patient will be delayed.

Lateral - "On the side"

Usually used for thoracotomies, renal, shoulder surgery and hip operations. The lateral position alters respiratory physiology: if breathing spontaneously, the dependent (lower) lung is efficiently perfused and ventilated. But with IPPV the dependent lung is better perfused and the non-dependent (upper) lung better ventilated, resulting in V:Q mismatch. Pressure points in this position are the dependent hip, shoulder and ankle and these should be padded where appropriate. The patient may be stabilised with chest and hip supports, or with a mattress which becomes rigid when air is evacuated from it. A pillow is placed between the legs, with the lower leg flexed at the knee and the upper leg in a neutral position. The upper arm may be allowed to hang freely above the head or placed in an arm support.

Lateral decubitus position for nephrectomy

The table is flexed in the centre in addition to the lateral position. The lateral decubitus position causes a V:Q mismatch as previously mentioned. This position can cause direct caval compression resulting in decreased venous return and hypotension. It is important to monitor blood pressure closely - an arterial line may be useful. Pressure points are the dependent hip, shoulder and ankle. Once again, the patient is stabilised with chest and hip supports or with a mattress which becomes rigid when air is evacuated.

Sitting

Occasionally for posterior fossa neurosurgical procedures. It has a number of advantages over the prone position: better surgical access, more neck flexion, improved gravitational drainage of blood. Serious disadvantages include: postural hypotension, high risk of venous air embolism. This position has marked cardiovascular effects: cardiac output and arterial pressure may decrease dramatically due to pooling of blood in the lower extremities with resulting hypotension and reduced cerebral blood flow. Invasive monitoring (arterial/ central lines) is required.

In order to minimise the effects of changing from supine to a sitting position, a number of measures can be taken. These include fluid loading, compression stockings or G-suits and/or the use of vasopressors. The patient should be raised slowly with elevation of the legs above the horizontal once in the sitting position to aid venous return. The head may be supported in a horseshoe headrest that allows pressure to be applied to the head and neck without movement. Alternatively a skull clamp may be used which minimises pressure-related complications involving the face. Its insertion is stimulating but may be attenuated by using local anaesthetic, a small bolus of propofol or a short acting opioid. Flexion of the head on the neck aids surgical access, but raises ICP and may cause swelling of the face and tongue because venous return is decreased. These patients are at marked risk of air embolism and should be monitored using $ETCO_2$, Doppler, transoesophageal ECHO or oesophageal stethoscope. The risk is reduced by IPPV and by maintaining mean arterial pressure. Spontaneous ventilation is permissible (indicates that respiratory centre is intact), but is seldom used now.

Armchair position for shoulder surgery

Occasionally an armchair position is adopted for surgical access. This position has cardiovascular effects similar to the sitting position namely, hypotension due to pooling of blood in the lower limbs.

These effects can be reduced by elevating the patient to a head up position slowly, using vasopressors and fluids as required, and elevation of the patient's legs above the horizontal. These patients are also at risk of air embolism.

Nerve	Site of Potential Damage	Result of Damage
Supraorbital	Compression from a tight facemask	Photophobia, pain in the eye, numbness of the forehead
Facial	Lies superficially and may be damaged at the ramus of the mandible	Paralysis of the face and orbicularia occuli (buccal branch)
Axillary	Prone to stretching when shoulders are extended and arms placed above the head (prone position)	Decreased abduction of arm, reduced skin sensation over lateral aspect of upper arm.
Radial	At risk of external pressure in axilla if arm hangs over the edge of table (posterior cord)	Wrist drop
Median	Very uncommon injury. At risk of direct needle trauma in artecubital fossa	Inability to oppose thumb and little finger
Ulnar	- May be compressed by edge of operating mattress where it lies superficially in groove behind medial epicondyle of humerous - Internal compression between two heads of flexor carpi ulnaris - Full flexion at elbow causes compression where the nerve enters the cubital tunnel	Hand weakness, tingling and pain
Sciatic	Main source of damage direct trauma from misplaced i/m injections pneumatic tourniquet	Paralysis of all muscles and sensory loss below knee
Femoral	Susceptible to damage where it passes beneath inguinal ligament - excessive leg flexion in lithomy may cause entrapment	Loss of hip and knee extension, loss of sensation over anterior thigh and anteromedial aspect of calf
Lateral cutaneous nerve of the thigh common peroneal	At risk if frames are used to support anterior superior iliac spines when the patient is prone may be compressed by lithomy pole where it passes around the head of the fibula (superficial)	Meralgia paraesthesia - numbness and hyperalgesia of the upper lateral thigh Foot drop, loss of sensation over lateral aspect of leg and dorsum of foot
Pudendal	Compression against perineal post used in hip surgery	Loss of perineal sensation, faecal incontinence
Saphenous	Compressed between medial tibial condyle and lithotomy pole (leg lateral to pole)	Sensory loss along medial aspect of calf

PERCUTANEOUS TRACHEOSTOMY

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Tracheostomy is a common surgical procedure performed on critically ill intensive care patients. Reports have documented considerable associated morbidity, with complication rates varying from 6 to 66%.[1-6] The reports on mortality associated with tracheostomy range from 0 to 5%.[4,5] Minimally invasive procedures are rapidly transforming many areas of surgical practice. Percutaneous tracheostomy, a minimally invasive alternative to conventional tracheostomy, was first described by Toye and Weinstein in 1969.[7]

Two new methods suitable for elective percutaneous tracheostomy at the bedside have been introduced based on the Seldinger technique. The Ciaglia method, developed by Ciaglia et al in 1985, uses graded dilators and is currently the most popular method. Another technique, described by Griggs et al in 1990, is a one-stage dilation technique using a modified Howard-Kelly forceps as the tracheal dilator.[9]

Percutaneous tracheostomy can be performed by an anaesthetist at the bedside in a controlled setting (ICU) with the assistance of nursing personnel without the need to transfer the critically ill patient to the operating theatre.

INDICATIONS FOR TRACHEOSTOMY[10]

- Facilitate weaning from positive pressure ventilation and sedation
- Bypass an obstruction of the upper respiratory tract.
- Prevent aspiration from the pharynx or gastrointestinal tract.
- Facilitate removal of secretion by aspiration.
- Facilitate long-term airway management

Conditions in which surgical tracheostomy may be safer than percutaneous tracheostomy:

- Emergency tracheostomy tube placement
- Difficult to palpate the anatomical landmarks:
  - very obese patients
  - short or bull neck
  - enlarged thyroid
  - nonpalpable cricoid cartilage
  - gross deviation of trachea
- Infection at or near the intended site for tracheostomy.
- In paediatric age group (controversial).[11] Children have a more compliant trachea than adults leading to a tendency to collapse when pressure is exerted with dilators.
- Previous neck surgery may distort the anatomy.
- In unstable cervical spine fracture.
- Required PEEP > 15 cm H_2O, as oxygenation may be compromised during the procedure.
- Malignancy at the site of tracheostomy.
- Uncontrolled coagulopathy, considered as a relative contraindication

Advantages of percutaneous tracheostomy over surgical tracheostomy:

- It is a relatively simple technique suitable for trained staff in the critical care setting.
- It does not require an operating theatre and the procedure is usually performed under local anaesthetic, sedation and neuromuscular blockade as appropriate.
- Forms a stoma between tracheal rings, resulting in reduced blood loss as there is usually no disruption of blood vessels. Moreover, the tracheostomy tube is fitted snugly in the stoma thereby minimising any tendency to bleeding after the procedure.
- Infection rates for percutaneous tracheostomy range from 0 to 3.3%, whereas those for open tracheostomy have been reported to be as high as 36%.[12,13]
- Stenosis rates for percutaneous tracheostomy range from 0 to 9%.[13,14] The reported incidence of late complications resulting from open tracheostomy such as tracheal stenosis, tracheomalacia, fistula and scarring varies widely.
- Small and neat stoma of dilatational tracheostomy generally results in a more cosmetic scar.

DESCRIPTION OF TECHNIQUES[10,15]

The primary requirement for performing percutaneous tracheostomy is the presence of a trained anaesthetist for managing the airway of the patient. They should be equipped with drugs and instruments for rapid sequence orotracheal intubation with a cuffed tracheal tube.

The patient should be adequately anaesthetised to avoid movements and should be monitored using standard techniques. The neck is extended by placing a sandbag under the shoulders and the area around the intended tracheostomy site is cleaned with antiseptic solution. The area is surrounded by autoclaved drapes.

The thyroid cartilage, cricoid cartilage and first three tracheal rings are identified by palpation. The desired space for tracheostomy is identified, which may be between 1st and 2nd or 2nd and 3rd ring. The cuff of the existing tracheal tube is deflated and the tube is withdrawn under direct laryngoscopy until visualisation of its cuff in larynx. The tracheal tube must be carefully stabilised at this time to prevent dislodgement and the cuff reinflated. Withdrawal is necessary to allow unimpeded passage of guide wire and dilators into the trachea. The use of a fibreoptic bronchoscope[16,17] reduces the risk of complications associated with percutaneous tracheostomy. It may be positioned

in the endotracheal tube to observe or check that the point of entry of the needle is through the centre of the anterior tracheal wall. Care must be taken not to damage the bronchoscope with the needle. Fibreoptic bronchoscopy also allows observation of the passage of dilators or entry of modified Howard-Kelly forceps, reducing the risk of damage to the posterior tracheal wall during the procedure and confirming the correct placement of the tracheostomy tube.

The patient should be preoxygenated by ventilation with 100% oxygen for at least 5 minutes before starting the procedure. The orotracheal tube should be kept in situ until ventilation can be transferred to the tracheostomy tube, which should be confirmed by auscultation of lungs and ideally by capnography. A laryngeal mask airway (LMA) may be used in place of orotracheal intubation[18,19] prior to tracheostomy in certain ICU patients eg those requiring relatively low inflation pressures to maintain adequate gas exchange, without the risk of aspiration of gastric contents.

Infiltration of the soft tissues of the intended site for tracheostomy with local anaesthetic (e.g lignocaine 1% with 1 in 200,000 adrenaline) is recommended to reduce bleeding.

A horizontal incision is made at the anticipated point of entry with a scalpel blade. Blunt dissection with forceps is carried out which allows palpation of the cricoid and the upper tracheal rings. A needle and cannula assembly is now carefully introduced in the midline, either between the first and second or between the second and third tracheal rings (figure 1). The needle is then slowly advanced with continuous aspiration until the position of the needle tip in the trachea is confirmed by aspiration of air.

A J-tipped flexible guidewire is threaded through the cannula into the trachea (figure 2) and the position checked using a fibreoptic bronchscope (if available). Next, a small, firm introducing dilator is slid over the wire, through the soft tissues into the trachea. The dilator is then removed, ensuring that the wire stays in place.

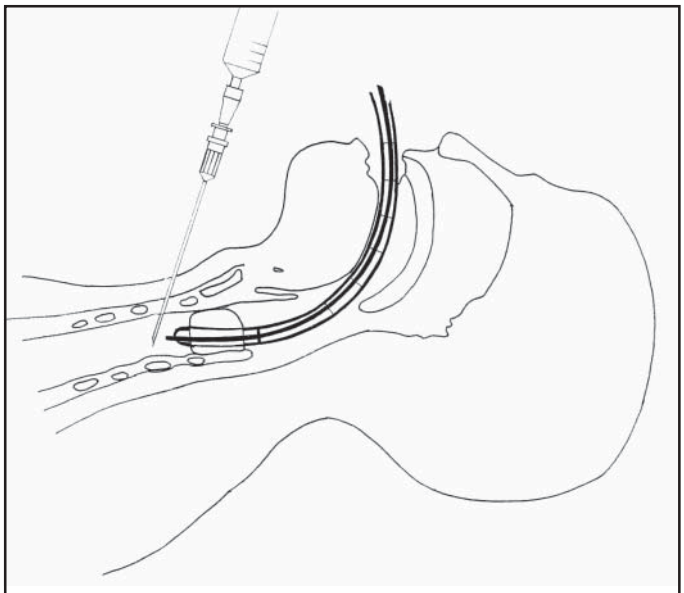

Figure 1:

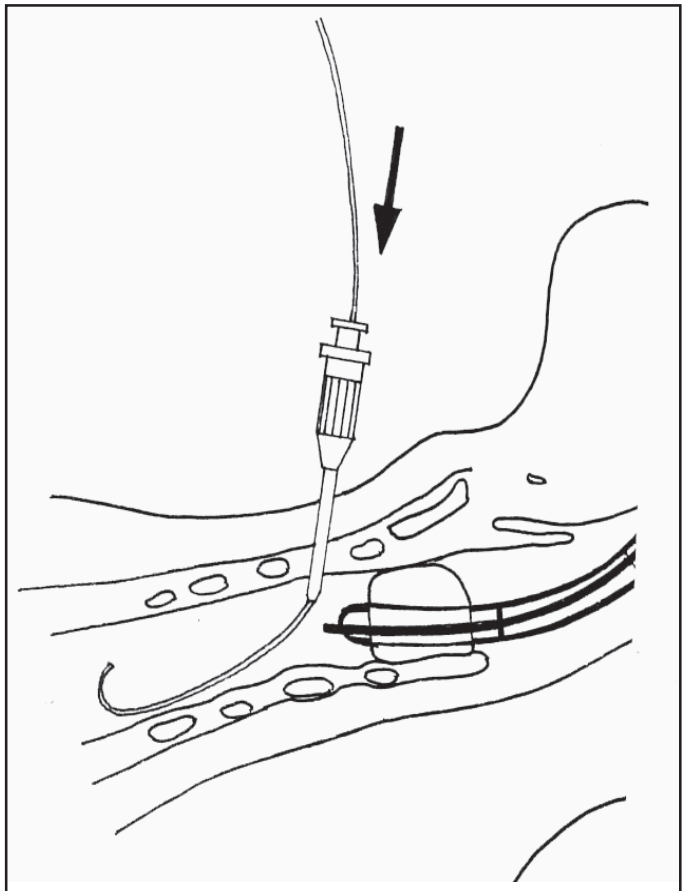

Figure 2:

In the dilatation or Ciaglia technique[8], the stoma is then dilated, using a series of curved tapered dilators (figure 3), starting with the smallest dilator. The dilator is slid over the 'guiding catheter' until the blunt end of the dilator aligns with the 'dilator-positioning' mark on the catheter. During dilatation, the tip of each dilator is lubricated with sterile aqueous jelly and pushed in and out several times with firm pressure. A twisting action or moving the dilator to and fro in the trachea may aid the dilation. The trachea is dilated gradually, up to two sizes above the dilator which fits the tracheostomy tube. Now, the tracheostomy tube is slid over the snugly-fitted and lubricated dilator (figure 4). The tracheostomy tube is also lubricated and both are then introduced into the trachea. Finally, the dilator, guide-wire and 'guiding catheter' are removed, leaving the tracheostomy tube in place. In the 'Blue Rhino' dilation technique (Cook, UK) the serial dilators are replaced by a single graduated dilator. The technique is otherwise similar.

In Grigg's technique[9], after the wire is in place, the dilator is removed and free movement of the wire is checked. The dilating (modified Howard-Kelly) forceps are advanced with the tip at the same angle of approach to the trachea as the wire to fashion the stoma. The handle of the forceps is lifted to the vertical position and is opened to tear the trachea between the rings. The blades of the forceps should lie in the trachea and parallel to it. The forceps are now withdrawn in the open position, ensuring that the stoma is large enough to admit the tracheostomy tube.

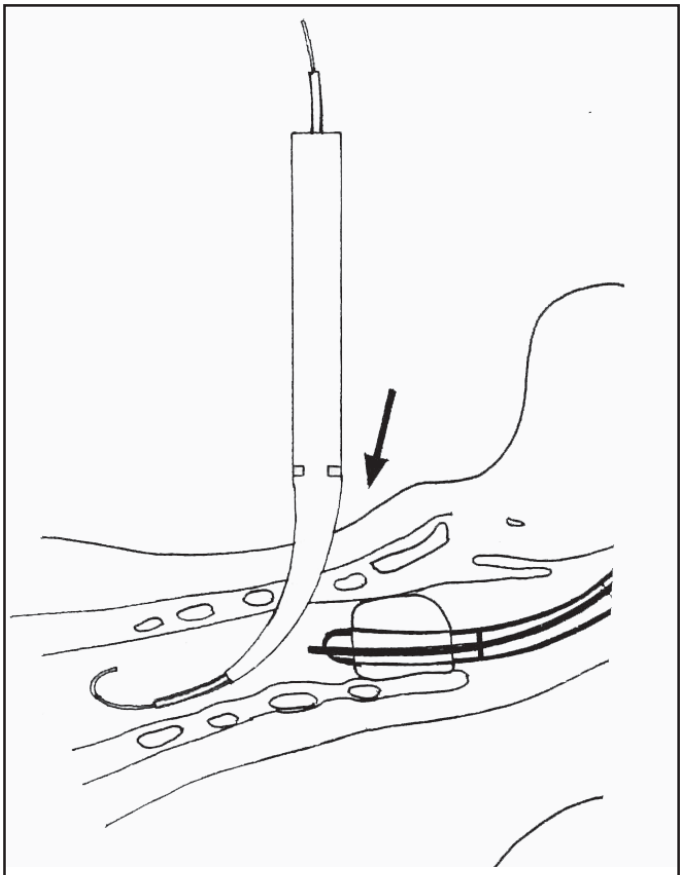

Figure 3:

The tracheostomy tube is slid with its obturator in place down over the wire into the trachea. The guidewire and obturator are then removed, leaving the tracheostomy tube in place.

The cuff of the tube is inflated, the ventilator breathing circuit is connected and the tube secured by tapes around the neck. Satisfactory ventilation is verified by auscultation of chest. The tube is then aspirated to remove blood and secretions. Presence of surgical emphysema at the site is also watched for, and chest X-ray is performed to check for tube position and pneumothorax. If a fibreoptic bronchoscope is inserted via the tracheostomy tube into the trachea, a satisfactory position can be confirmed.

COMPLICATIONS

Although complications are similar to surgical tracheostomy, the incidence is low. There is some evidence to suggest a lower incidence of complications with percutaneous, rather than formal surgical tracheostomy. However, it appears difficult from these studies to distinguish the effect of the experience of the operator from the chosen technique employed upon the complication rate. One study cites the overall mortality rate with percutaneous tracheostomy to be 0.3% as compared to 3.2% for surgical tracheostomy.[20] The incidence of tracheal stenosis was 3.3% (surgical tracheostomy 6.6%) and an overall complication rate was around 15% (surgical tracheostomy 42%).

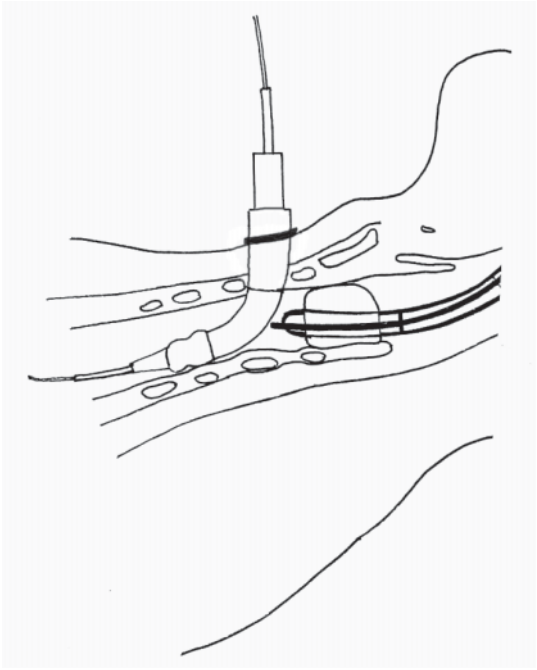

Figure 4:

COMPLICATIONS OF INSERTION

Early

- During the procedure, the patient may develop hypoxia due to failure of ventilation. Furthermore, ventilation of the patient may also be difficult if the cuff of the endotracheal tube is inadvertently punctured. If any difficulties are encountered on insertion of the tracheostomy tube, the existing endotracheal tube should be advanced beyond the incision in the trachea and ventilation recommenced until the patient is stable enough to resume the procedure.

- The patient may develop pneumothorax, pneumomediastinum or creation of a false passage and subcutaneous emphysema due to the placement of the tracheostomy tube in the paratracheal space.

- Damage or injury to the posterior tracheal wall may lead to tracheo-oesophageal fistula.

- Major bleeding is unusual. Minor bleeding can usually be controlled by pressure or occasionally a suture. Haemorrhage into the airway is potentially dangerous as it may result in a blood clot obstructing the airway.

- Needle puncture on the lateral wall of trachea may subsequently lead to stenosis.[21]

- Dislodgement of the tracheostomy tube soon after the procedure may be hazardous as the entry to the trachea is small and deep, hence replacement of the tube may be impossible. The percutaneous tracheostomy tube should not be pushed blindly back in but replaced after proper dilation of the track following orotracheal reintubation.

- Secondary haemorrhage may occur either from infection or erosion of vessels.

Late

The incidence of clinically significant subglottic stenosis is low in percutaneous tracheostomy. The reasons behind the development of subglottic stenosis include laryngeal oedema, damage to the tracheal mucosa, high pressure exerted by the endotracheal cuff and prolonged translaryngeal intubation.[22,23] However in some series, the incidence of subglottic stenosis in percutaneous tracheostomy is lower than that in the open surgical tracheostomy group.

Conclusion

Percutaneous tracheostomy is a useful procedure for airway management in ICU. The chief advantage of the technique is that, it can be performed at the bedside, at the convenience of ICU staff and without disrupting treatment or monitoring of critically ill patients. Studies have shown significant cost saving in Western countries.[15] The main limitations of percutaneous tracheostomy in our country are the high cost and scarcity in the availability of the kit. Were it possible to sterilize and re-use components of the kit this expense might be reduced.

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ANAESTHESIA FOR THE PATIENT REQUIRING EMERGENCY ABDOMINAL SURGERY

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Introduction

The principles of anaesthesia for the patient requiring emergency abdominal surgery are common to adults and children, and to the patient and their anaesthetist wherever they are, and whatever resources are available. Within this framework, the article will address the importance of attention to:

- Airway
- Breathing
- Circulation
- Drugs
- Equipment
- Fluids and electrolytes

The major part of the article is about general anaesthesia, with some comments on regional anaesthesia, which may be the only option on some occasions.

The Anaesthetist and the Environment

The anaesthetist has to bear in mind a number of things when preparing to anaesthetise a patient for emergency abdominal surgery. This not only includes the patient's condition, and the nature of the surgery, but also the anaesthetist's own knowledge and experience, the anaesthetic equipment, and the consumables and drugs which are available.

The anaesthetist must take into account issues such as the knowledge and experience of the surgeon, the availability of an anaesthetic assistant, and the reliability of services such as oxygen, suction and power. For emergencies, particularly, there is often no second chance should a crisis occur, and if fall-back plans have not been made before starting the anaesthetic.

Pre-Anaesthetic Check

The operating theatre needs to be always ready for an emergency procedure, so the anaesthetist does not have to waste time cleaning up and finding things used in the previous case. A systematic approach is necessary. An example is to check the following (Table 1).

Table 1 **Pre-Anaesthetic Checklist**

- Fresh Gas Supply
- Gas Delivery System
- Anaesthetic Gases
- Anaesthetic Agents
- Breathing Circuit
- CO_2 Absorber
- Airway Equipment
- Breathing Equipment
- Circulatory Equipment
- Monitors
- Resuscitation Drugs
- Resuscitation Equipment

- **Fresh gas supply** - is it air, or oxygen. If it is oxygen, is it supplied by an oxygen concentrator, a cylinder, or from a wall outlet? What reserves are there in theatre or in the bulk supply?

- **Gas delivery system** - is it draw-over, demand flow, or continuous flow?

- **Anaesthetic delivery** - will nitrous oxide be used? Is the main agent ether, halothane, enflurane, isoflurane, sevoflurane? Is the vaporiser full, and does it work? Is it draw-over or plenum? Is there extra agent available?

- **Breathing circuit** - does it have carbon dioxide absorption or not? If so, is it fresh? Is the circuit intact, and does it work?

- **Airway equipment** (Figure 1, Table 2) - Are there airways of various types and sizes - oropharyngeal, nasopharyngeal, endotracheal tubes, laryngeal masks? Are an endo-tracheal tube introducer and a bougie immediately available? Are there a syringe, clamp, tape, Magill's forceps, catheter mount available? Is there a way to insufflate the trachea with oxygen if the patient cannot be ventilated or intubated? Can an emergency cricothyroidotomy be performed? Is there effective suction with handpieces and catheters?

- **Breathing equipment** - Are there face masks of various types and sizes? What is the main ventilating system? Is there a self-inflating bag in reserve? Is the equipment for emergency decompression of a tension pneumothorax available? Is there a ventilator for long cases?

- **Circulatory equipment** - What intravenous equipment is there? - syringes, needles, catheters, fluids, ability to infuse under pressure, ability to warm intravenous fluids.

- **Other equipment** - What equipment is available to warm or cool the patient? What monitoring equipment is there that works and has been checked. Complete monitoring can be listed as follows, bearing in mind that some hospitals will have all of it, and some will have very little.

- Clinical monitoring by the anaesthetist, of the patient, the surgery and the equipment.

- Pulse, colour, blood pressure, perfusion, skin feel.

- Chest movement, breath sounds.

- Pupil size, lacrimation

- Temperature, urine output.

- Pulse oximetry (the most useful electrical monitor)

- Capnography (the second most useful electrical monitor)

- ECG(the third most useful electrical monitor)

- Airway pressure, tidal and minute volumes

- Blood sugar, haemoglobin level, blood gases
- CVP monitoring equipment
- Nerve stimulator
- Defibrillator

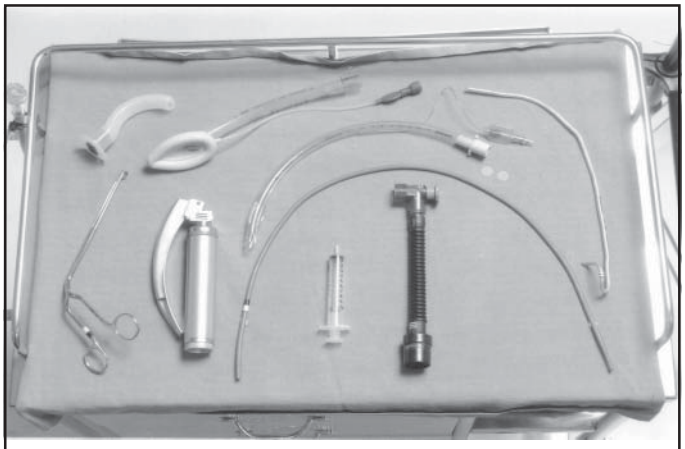

Figure 1: Airway Equipment

Table 2 **Airway Equipment**

- Suction Device
- Oral/Nasal Airways
- Laryngoscopes
- Endotracheal Tubes
- Syringe/clamp/tape
- Introducer/Stylet
- Bougie
- Magill's Forceps
- Laryngeal Mask Airway
- Cricothyroid Insufflation Equipment
- Cricothyroid Equipment

For **children**, is all the equipment of the appropriate type and size?

- Drugs - There are so many, and the choice between them is often based on arguments which may be relevant in some environments and not in others

- Intravenous induction agents (Table 3) - thiopentone is still the commonest agent world-wide, challenged by ketamine in some places, propofol in others.

- Inhalational agents (Table 4) - ether and halothane are common in many parts of the world, enflurane, isoflurane, sevoflurane in others.

- Hypnotics - diazepam remains common, but midazolam is more useful in anaesthesia because of its more rapid onset and shorter duration of action.

- Opioids - morphine is still widely used, and pethidine less frequently. Fentanyl is increasingly used in anaesthesia because of its short duration of action.

- Other analgesics such as paracetamol or indomethacin suppositories.

Table 3 **Intravenous Agents**

Drug	Typical Initial Dose	Clinical Onset	Clinical Duration
Thiopentone	4-5 mg/kg	20-30 sec	5-10 min
Propofol	1.5 – 2.5 mg/kg	1-2 min	5-10 min
Midazolam	0.01-0.1 mg/kg	2-4 min	1-2 hrs
Diazepam	0.02-0.2mg/kg	3-6 min	4-8 hrs
Fentanyl	1-1.5 mcg/kg	1-4 min	2-3 hrs
Morphine	0.05-0.15 mg/kg	3-10 min	2-3 hrs
Pethidine	0.5-1.5 mg/kg	2-5 min	2-3 hrs
Ketamine	1-2 mg/kg	20-30 sec	5-10 min

Table 4 **Inhalation Agents**

Agent	MAC*	Concentration used	Blood/Gas partition coefficient	Oil/Water Solubility
Ether	1.92	2-15%	12	3
Halothane	0.76	0.5-3%	2.3	220
Enflurane	1.68	1-6%	1.9	120
Isoflurane	1.15	1-4%	1.4	120
Sevoflurane	2	1-6%	0.69	53
Nitrous Oxide	104	70%	0.47	2.2

*with 60% nitrous oxide. MAC is higher if no nitrous oxide is used

- Muscle relaxants (Table 5) - Suxamethonium is still the choice for emergencies. Non-depolarising relaxants are now many, and may be short, medium or long acting, with specific advantages and disadvantages. Vecuronium, atracurium and rocuronium are rapidly overtaking pancuronium in many places. d-tubocurarine, alcuronium and gallamine are still used in some countries.

- Other essential drugs include atropine, neostigmine, adrenaline, ephedrine, an anti-hypertensive, a bronchodilator, a diuretic, an anti-emetic, and emergency resuscitation drugs (atropine, calcium, adrenaline, lignocaine) (Table 6).

- Local anaesthetics - lignocaine, bupivacaine, ropivacaine, cinchocaine.

Pre-Operative Assessment and Resuscitation

A systematic approach is best - it avoids overlooking important matters. For the patient requiring emergency abdominal surgery, with few exceptions, there is time to assess properly, and to resuscitate, before induction of anaesthesia. Most sensible surgeons understand this. Even in the few surgical emergencies where time to surgery is critical, the anaesthetist must still have essential information before proceeding.

Bear in mind that patients (and surgeons) do not tolerate unnecessary delays. If the patient needs investigations and/or resuscitation, organise it yourself, then you know it has been done properly. Don't "leave it to someone else". If surgery has to be delayed for resuscitation, agree on a time with the surgeon (see case insert).

Table 5 **Muscle Relaxants**

Drug	Initial dose mg/kg	Approximate Duration (min)
d-Tubocurarine	0.5	25-30
Alcuronium	0.3	20-25
Gallamine	1-2	20-30
Pancuronium	0.1	30-45
Vecuronium	0.1	15-20
Atracurium	0.5	20-25
Cisatracurium	0.15	20-25
Mivacurium	0.2	10-20
Rocuronium	0.6	20-30
Suxamethonium	1-1.5	3-5

Table 6 **Resuscitation Drugs**

Drug	Recommended Dose	Average Adult Dose
Adrenaline	0.01-0.05 mg/kg	0.5-1 mg
Atropine	0.02 mg/kg	0.6 – 1.2 mg
Calcium Chloride	0.2 ml/kg (10%)	5 – 10 mL
Lignocaine	1 mg/kg	10 mL 1%

There are some situations where the patient must go to theatre immediately - they include severe foetal distress, uncontrollable internal haemorrhage, rapidly expanding intracranial lesion (e.g. extradural haematoma). In these situations, history, examination, resuscitation have to be done "on the run" and with no delay. In most other situations, a short delay for resuscitation is best for the patient.

A good approach is to divide pre-operative assessment and resuscitation into two phases - initial (rapid), and definitive (when there is more time). In the **history**, essential questions are:

- When did you last eat or drink? (But regard these patients as having a full stomach anyway.)
- Have you any allergies?
- Are you taking any medications, smoking, drinking, using drugs or remedies?
- Have you had any problems with previous anaesthetics?
- Heart problems, chest problems, kidney or liver problems?
- Diabetes?
- Heartburn or reflux?
- Fits, faints, or funny turns?
- Bleeding tendency?
- Pregnancy?
- Infectious disease? - especially HIV/AIDS, Hepatitis, Malaria, TB

In the physical **examination**, look particularly for evidence of

- Difficult airway
- Respiratory abnormalities
- Cardiovascular abnormalities

Investigations may not be available, or not available in the time frame. Haemoglobin, urea, creatinine, electrolytes, Chest X-Ray and ECG are still the most useful.

Investigations may be clinical, or laboratory. Clinical investigations are part of physical examination, and include the "bedside forced expiratory volume", measured with a spirometer, or by listening to rapid exhalation. Laboratory investigations should always be requested if they will help to identify a problem which can be corrected. Once ordered, they must be checked and acted upon. Once again, they may or may not influence a clinical decision to delay the operation, or to proceed.

Of the more commonly available investigations, Haemoglobin value must be interpreted in the context of the usual Hb of the population (which may be 8-9gm/dl in some areas, 12-13gm/dl in others) as well as in the context of bleeding or dehydration. A Hb of 8gm/dl in a bleeding or dehydrated patient may really be 5gm/dl when resuscitation is complete, and vascular volume is expanded, so blood transfusion may be indicated early.

Blood sugar (or urinalysis for glucose) should always be measured to allow correction in the diabetic, and to detect diabetic ketoacidosis masquerading as an abdominal emergency.

Urea and Creatinine and Electrolytes may be helpful, but should be interpreted in the context of the clinical picture, and information about whether the patient has pre-existing renal failure.

Elevation of urea and creatinine may simply indicate dehydration and poor renal blood flow, or it may indicate acute or chronic renal failure. Fluid resuscitation should proceed whatever the cause, to ensure renal blood flow is improved.

Serum sodium, potassium, chloride and bicarbonate may be "normal" or "abnormal". The first step in the acute abdominal emergency is again expansion of intravascular volume and fluid resuscitation. If renal function can be restored, the kidneys will correct the electrolyte disturbance.

Chloride and bicarbonate tend to balance each other - if one goes up the other goes down. Hypochloraemia (as in pyloric stenosis) will correct with normal saline infusion, but be made worse with Hartmann's solution, because of the lactate, which is converted to bicarbonate. A low bicarbonate usually indicates metabolic acidosis due to poor perfusion, and corrects as the circulation improves.

Administration of bicarbonate is not often advisable, because it combines with hydrogen ions and results in formation of carbon dioxide which must be excreted by increased ventilation. Its acidosis-correcting effect is thus short-lived.

Arterial blood gases are the only accurate way of obtaining:

- PaO_2 (Oximetry is a substitute provided perfusion is good)
- $PaCO_2$ (End tidal CO_2 is a substitute but in the critically ill patient, there may be a wide gap between the $ETCO_2$ and the higher $PaCO_2$, not the normal 6mmHg)

- pH
- HCO_3 (which may differ from that measured with serum electrolytes)
- Identification of whether an acid-base disturbance is an acidosis or alkalosis, whether either is primarily metabolic or respiratory, and whether there is secondary compensation for the primary disturbance.

Chest X-Ray is often useful in patients with abdominal emergencies when history and examination are not clear cut, particularly in obese patients. Look carefully for pneumothorax, haemothorax, effusion, evidence of stomach or bowel in the chest, abnormalities in the lung fields (basal atelectasis is common), size and outline of the cardiac shadow.

ECG may indicate ischaemia, atrial or ventricular enlargement, abnormalities of electrolytes (as in the peaked T waves of hyperkalaemia), arrhythmias.

Assess the risk for this patient. Were they perfectly healthy before the emergency, or did they have mild systemic disease, significant systemic disease, or life-threatening systemic disease now complicated by an emergency?

Be aware of common conditions in the population which will influence resuscitation and anaesthesia, as well as postoperative care. These may include:

- Diabetes
- Ischaemic heart disease, cardiac failure, hypertension
- Valvular heart disease
- Asthma, chronic respiratory disease
- TB - especially of pleura and pericardium
- HIV/AIDS
- Malaria
- Anaemia
- Liver disease, renal disease

Identify, pre-operatively if possible, those patients who will benefit from close observation and care post-operatively in the High Dependency or Intensive Care Unit. You may be responsible for care of the patient there. If not, make sure the handover is good, and that you are available to help if there are problems.

Resuscitation goes hand in hand with assessment

- Airway problems such as in severe facial injury must be managed before induction of anaesthesia.
- Oxygen should always be given to the critically ill patient.
- Breathing problems such as asthma or pneumothorax must be treated before induction of anaesthesia.
- Circulation problems such as hypovolaemia, or cardiac tamponade must be treated before induction of anaesthesia.
- Other emergencies, such as hyperglycaemia and electrolyte or acid-base abnormalities must have treatment commenced before induction of anaesthesia.
- Consider the need for a nasogastric tube. Decide when to insert the urinary catheter.

Resuscitation must be aggressive before and during anaesthesia. The only excuse for induction prior to resuscitation is if the patient has a condition which cannot improve without surgery. This may include massive intra-abdominal haemorrhage. Even then, resuscitation must begin before anaesthesia is induced.

Which fluids should be used in resuscitation depends on the cause of the problem, and what is available. (Table 7). In an adult with intra-abdominal bleeding, the choice is clearly blood and plasma expanders such as Haemaccel or Gelafundin or Gelafusin or Dextran, supported by crystalloids - normal saline or Ringer lactate (Hartmann's) solution. In a patient with intra-abdominal sepsis, the same approach may be needed, but blood transfusion will depend on the haemoglobin level once vascular volume has been restored. In an adult with bowel obstruction who is not shocked, saline or Hartmann's solution may be adequate. In an infant with pyloric stenosis, saline is required initially, and Hartmann's solution will make the hypochloraemic metabolic alkalosis worse.

What fluids to give, and how much, depends on the cause of the emergency. Every patient with shock is an opportunity to revise your cardiovascular pathophysiology.

Table 7 **Intravenous Fluids**

Fluid	Na^+ mmol/L	K^+ mmol/L	Cl^- mmol/L	HCO_3^- mmol/L	Ca^{++} mmol/L	Mg^{++} mmol/L
N/Saline	154	-	154	-	-	-
Hartmann's	131	5	111	29*	2	-
4% Dextrose in $^N/_5$ Saline	31	-	31	-	-	-
5% Dextrose	-	-	-	-	-	-

** as lactate*

Tissue perfusion of the whole body depends on an adequate cardiac output. Cardiac output depends on:

- Myocardial contractility, which is influenced by
  - End diastolic ventricular volume
  - End systolic ventricular volume
  - Myocardial integrity
- End diastolic volume, or the volume of each ventricle before it contracts, is influenced by
  - End systolic volume
  - Preload
- End systolic volume, or the volume of each ventricle at the end of contraction, is influenced by
  - End diastolic volume
  - Afterload
- Preload - venous return to the atria depends on blood volume, vascular capacitance (matching of blood volume to vascular capacity), posture, venous valves, limb muscle activity, intrathoracic pressure changes, functioning cardiac valves, normal atrial contraction, and a reasonable heart rate to allow time for ventricular filling.
- Afterload - ejection of the stroke volume into the aorta is influenced by the ability of the arterial bed to receive the volume, so that vasoconstriction requires extra cardiac work to generate the pressure required to eject the blood.

- Myocardial integrity depends on the cardiac muscle having glucose and oxygen to allow it to function properly. It will be impaired if there is myocardial ischaemia, some electrolyte imbalances, or if there are toxins (from sepsis) affecting it, or if it is exposed to high concentrations of some anaesthetic agents (intravenous or inhalational).

In an abdominal emergency, the main problem resulting in poor tissue perfusion may be

- Hypovolaemia (as in haemorrhage)
- Hypovolaemia plus vasodilatation (as in sepsis)
- Hypovolaemia plus vasodilatation plus myocardial depression (as in sepsis).

In all cases, apart from giving oxygen, the most important thing to do is to correct the hypovolaemia, start antibiotics, then review and rethink. In sepsis, use of a "vasopressor" may be wise after correction of the volume deficit. Although there are several available, the cheapest and most useful is the catecholamine adrenaline. If the patient is moribund, intermittent doses of 0.1-0.5mL of 1:10,000 adrenaline may buy time until an infusion of 3-12mcg/minute can be set up (3mg adrenaline in 50mL normal saline run at 3-12mL/hour).

Note that in a resuscitated patient, it may take several hours for urine output to improve, even though the perfusion, blood pressure and pulse rate improve rapidly. In every patient, monitor the effects of the drug used to check that the desired effects are being achieved.

How fast fluids should be administered depends on the estimated deficit and the time available to ensure the circulatory volume is adequate before induction of anaesthesia. Always use large bore IV cannulae - more than one if necessary. The aim is to have a patient who is conscious, pink, well perfused, with a reasonable pulse and blood pressure prior to induction. Particular care is required in the very young and the very old.

Case Insert

A 30 year old male has been admitted with peritonitis, thought to be due to bowel perforation from typhoid, present for 3 days. He is shocked, with a temperature of 38°C, a pulse of 120/minute, BP 70 mmHg systolic, poor nail bed capillary return, respiratory rate 30/minute, confused. There are no facilities for immediate investigations of any sort. Urinary catheterisation results in 20mL of concentrated urine. The surgeon wants to operate immediately. The anaesthetist **does not** say "Yes", or "call me when the patient is resuscitated". The anaesthetist **does** ask the surgeon to assist in resuscitation following the ABC sequence, planning to resuscitate with oxygen, IV fluids, and administer antibiotics.

This patient could be deficient in fluids to the extent of at least 8-10 litres or more, (2 litres per day x 3 days of maintenance fluids plus fluid lost by vomiting/diarrhoea, plus fluid pooled in the bowel and peritoneal cavity). Induction of general anaesthesia in this state will probably cause death. The first priority is restoration of intravascular volume with a colloid such as Haemaccel/Gelofundin/Gelofusin or Dextran given rapidly, until the pulse rate is down, the blood pressure is up, nail bed perfusion has improved, and the patient's mental state has improved.

If colloids are not available, use a crystalloid such as normal saline or Hartmann's solution. Higher volumes of crystalloids will be required because of their rapid distribution throughout the extracellular fluid space. Once the patient has acceptable vital signs and looks better, run saline or Hartmann's solution rapidly while getting ready for theatre. If **you do the resuscitation**, the patient may be ready for induction of anaesthesia in 1-2hours. **If you delegate the resuscitation** and wait for a phone call, the patient may never survive to get to theatre.

Preparation of the Patient for Theatre

Two questions which arise after assessment of the patient has been completed, and resuscitation is underway, are what about fasting and what about premedication?

In an abdominal emergency it is always assumed that the stomach is full, and that an emergency rapid sequence ("crash") induction and intubation of the trachea will be carried out. There is no need to fast, but there is a need to decide whether emptying the stomach by nasogastic tube is advisable - as in bowel obstruction, when vomiting or regurgitation of large amounts of fluid may result in aspiration or hypoxia.

Pre-medication should be restricted to use of opioids intravenously for analgesia, and atropine if ether or ketamine are to be used. Hypnotics should not be given, because they increase the risk of regurgitation and aspiration in these patients. Antiemetics will not be effective. Antacids and H_2 antagonists are most effective for the emergency patient with an empty stomach, which is rare.

Make sure that any resuscitation measures commenced are continued up to the time of induction of anaesthesia.

Induction of Anaesthesia

There are two phases, the "countdown" to induction, and induction itself. The "countdown" is the short period of checking that everything is ready, and nothing has been missed. (Table 8). This is when the patient is on the operating table, the assistant is ready to do anything required, including hand you the sucker, apply cricoid pressure reliably and effectively, and tilt the table head down on request. The anaesthetic machine, equipment and drugs have been prepared and checked. The intravenous line(s) is running well. The surgeon is scrubbed and the nurses waiting. The monitors are checked, and readings noted. 100% oxygen has been administered for 5 minutes. Now it is time to start the induction sequence, informing the patient that they will feel sleepy shortly, and that pressure will be applied to their throat (Table 9).

The intravenous induction agent is given slowly until the patient does not respond, bearing in mind that the circulation time may be slow in these patients. Cricoid pressure is applied suxamethonium is given, and tracheal intubation performed as soon as the fasciculations start to fade. The cuff is inflated, and the patient ventilated with a few breaths of 100% oxygen while checking the position of the tube. The tube is then secured.

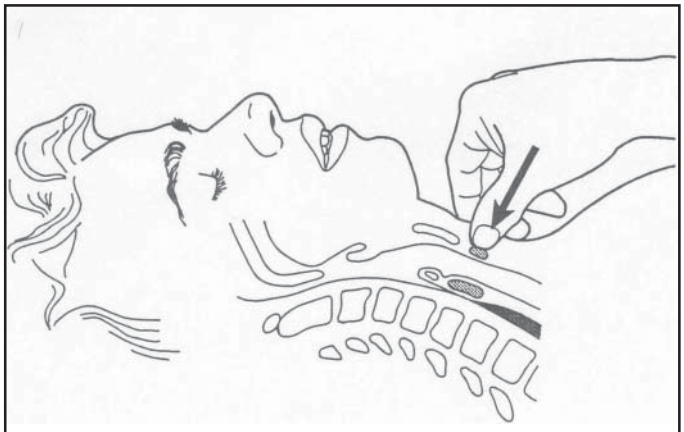

Figure 2: Cricoid pressure

How do you know the tube is in the trachea? (Table 10). Because you saw it pass through the vocal cords, heard bilateral breath sounds, with no noise over the epigastrium, and the chest moved uniformly up and down. What else is useful? Capnography is the gold standard, disposable colour-change discs are the next best. Without either of these, aspiration of the endo-tracheal tube with a large syringe will reveal easy aspiration of air if the tube is in the trachea, with a vacuum if it is in the oesophagus.

Table 8 **Pre-Induction 'Countdown'**

- Patient
- Surgeon
- Assistant to Anaesthetist
- Machine Check
- Airway Management
- Breathing Equipment
- Circulation Equipment
- Anaesthetic drugs are drawn up
- Resuscitation drugs are available
- Intravenous
- Pre-Oxygenation
- Vital Signs
- Monitors

Table 9 **Induction Sequence**

- Give 100% oxygen
- Complete pre-induction 'Countdown'
- Assistant ready
- Thiopentone +/- fentanyl
- Suxamethonium
- Cricoid pressure
- Endotracheal tube insertion
  - Cuff up
  - Check position
  - secure tube
- Non-depolarising relaxant
- O_2/gas/vapour
- Check vital signs/monitors
- Check patient safety

If at this stage you are unable to intubate or ventilate the patient, tell the surgeon, and start the protocol you worked out before you started. Maintain oxygenation, maintain cricoid pressure and follow the sequence shown in Table 11.

Table 10 **Is the Tube in the Trachea**

- See it pass through the cords
- Chest moves uniformly
- Hear bilateral breath sounds
- No noise over epigastrium
- Capnography trace
- Free air on aspiration of ETT
- O_2 saturation/colour maintained

Table 11 **Failed Initial Intubation**

- Call for help
- Maintain cricoid pressure
- Ventilate with 100% O_2
- If you can ventilate
  - Reposition head
  - Manipulate larynx
  - Suction larynx
  - Use introducer or bougie
  - Reintubate with smaller ETT
- If you can't ventilate
  - Consider LMA
  - Consider cricoid insufflation
  - Consider cricothyroidotomy
  - Consider waking patient up

Maintenance of Anaesthesia

Maintenance of anaesthesia (Table 12) may be achieved with nitrous oxide, oxygen and a volatile agent. If there is no nitrous oxide or it is contra-indicated, an air/oxygen mixture and volatile agent can be used. If there is no oxygen, just air and volatile agent, bearing in mind that the amount of the anaesthetic agent required will be higher than if it is used with nitrous oxide. If there is no air, oxygen and volatile agent can be used. A non-depolarising muscle relaxant and intermittent positive pressure ventilation allows the best conditions for the surgeon. If there are no relaxants, controlled or assisted ventilation will still assist the surgeon.

The maintenance phase requires observation and monitoring of the patient, and of the surgery, with particular attention to fluid and blood loss. If major surgery is proposed, or if the patient was dehydrated or hypovolaemic, measurement of urine output is a good guide to renal perfusion. Keep a careful record of anaesthetic agents, monitored variables, fluid and electrolyte balance.

Potential anaesthetic problems that may occur are the development of high or low airway pressure, desaturation of haemoglobin, abnormalities in the capnometry trace, hypotension, hypertension or arrhythmias. For each scenario, have a plan of how to find the cause of the problem in a logical way. (Table 13).

Table 12 **Maintenance of Anaesthesia**

- Maintain Anaesthesia
  - Agents/gas mixture
  - Opioids
  - Relaxants
  - Monitor
  - Vital Signs
- Monitor
  - Blood loss
  - Fluid/blood replacement
  - Urine output

Monitoring

The most important monitoring of the patient is clinical, including pulse, blood pressure, colour, respiration, pupil size, lacrimation, in addition to monitoring the surgical field, blood loss, urine output, fluid input. Heart sounds are useful to monitor particularly in children.

Table 13 **Checking Problems**

- High Airway Pressure
  - Misplaced airway/ETT
  - Blocked airway/ETT
  - Kinked airway/ETT
  - Bronchospasm
  - Tension pneumothorax
  - Sticking valve
- Low airway pressure
  - Where is the leak ?

  Desaturation of Haemoglobin
  - Oxygen supply failure
  - Oxygen delivery failure
  - Poor ventilation
  - Poor perfusion
  - Artefact
- Abnormal CO_2 trace
  - Ventilator problem
  - Circuit problem
  - Circulatory problem
  - Air embolism
  - Artefact
- Hypotension - identify cause and treat
- Hypertension - identify cause and treat
- Arrhythmias - identify cause and treat

The next important set of instrument monitors are pulse oximetry, end tidal CO_2 monitoring, ECG and temperature.

If available, CVP monitoring may be a useful guide, particularly in the patient who you think has had adequate fluid/blood replacement, but who remains hypotensive. Supported by a high CVP reading, this may be an indication for adrenaline infusion rather than more fluid, provided all other causes of hypotension have been looked for (e.g. pneumothorax, excess anaesthetic agent).

Other forms of monitoring in the critically ill patient might include an arterial line for BP and blood gas sampling, and occasionally a pulmonary artery catheter, which may show that despite a high CVP, the left atrial pressure, as reflected by the pulmonary capillary wedge pressure, is low.

Neuromuscular function monitoring is helpful in those patients who do not breathe well after reversal of muscle relaxants.

In situations where they are available, monitoring of inspired and expired oxygen, nitrous oxide and volatile agent should be used. Airway pressure, tidal and minute volume measurements likewise should be used if available.

Reversal of Anaesthesia

The end of surgery is the beginning of the next challenging period for the anaesthetist. It requires planning, like it did before induction. A "countdown" (Table 14) ensures that the sequence of timing of cessation of the volatile agent, reversal of the muscle relaxant with atropine and neostigmine, return of spontaneous ventilation, suction of the mouth and pharynx, and extubation of the patient occur smoothly (Table 15). Again, the assistant must be ready to start suction, and tilt the table if required.

Table 14 **Reversal 'Countdown'**

- Check Equipment
- Check drugs
- Assistant ready
- Turn off agents
- Give 100% oxygen
- Suction
- Reverse relaxant
- Check Observations
- Wait for adequate breathing
- Wait until patient wakes up
- Extubate
- Give 100% O_2 by mask
- **DO NOT LET THE PATIENT MISS A BREATH**

Table 15 **Reversal Sequence**

- Check
  - Vital signs/monitor
  - Surgeon is finishing
  - Assistant ready
  - Time of last dose of relaxant
  - Signs of reversal
- Check "Countdown" complete
- Extubate
- Turn patient on side
- Check airway is clear
- 100% O_2
- **DO NOT LET THE PATIENT MISS A BREATH**
- Check vital signs/monitors
- **ALL HANDS** to move patient
- Transfer to recovery

A final check of observations, and the patient's ability to maintain their airway, ventilation and oxygenation, and movement to the bed or trolley and transfer to Recovery can proceed. But a number of things can go wrong at this stage. There may be inadequate muscle relaxant reversal, and more reversal agent may be required, or extubation may have to be delayed; extubation may be followed by regurgitation or vomiting and aspiration; there may be laryngeal spasm. On the circulatory side, hypotension may occur while attention is concentrated on airway and breathing. A plan for each of these events must have been made, so that no time is lost in detecting and correcting the problem.

Recovery Room Care

Care in the Recovery Room must equal that during anaesthesia until the patient is capable of looking after their own airway and breathing, and is fully conscious. Again, use a systematic approach (Table 16). Any problems must be identified and treated rapidly (Table 17).

Table 16 **Recovery Care**

- Check vital signs/monitors
- Check level of consciousness
- Continue oxygen
- Check wound
- Check urine output
- Check respiratory rate, sedation, pain score
- Check temperature
- Give analgesics as required IV
- Check fluids and IV sites

Table 17 **Some recovery Problems**

- Inadequate breathing
- Regurgitation/vomiting/aspiration
- Laryngeal spasm
- Hypotension
- Not waking up

The patient in Recovery should continue to receive oxygen, have continuous monitoring of airway, breathing and circulation, and be given analgesia as required. Specific problems require a plan. If the patient fails to breathe adequately, is it due to inadequate reversal of relaxants, to the persistence of anaesthetic agents and opioids? Have they continued to bleed or lose fluid since the anaesthetic finished, and become hypovolaemic? If the patient fails to wake up, is it because of the drugs given, hypoxia, carbon dioxide retention, hypoglycaemia, hypothermia, or a medical complication?

Postoperative Care

The anaesthetist is often the best resource a surgeon has to advise on post-operative problems such as pain relief (Table 18), management of nausea and vomiting, fluid and electrolyte replacement. Get in the habit of visiting all emergency patients in the ward. You may be able to help, and you can make a note of any problems recorded on your anaesthetic record or the recovery record, as well as picking up anything that developed later which the surgeon believes may be due to the anaesthetic. You can also encourage early mobilisation and chest physiotherapy to minimise postoperative complications such as atelectasis, pneumonia, and deep venous thrombosis.

Table 18 **Post Operative Pain relief**

- Opioids
  - Titrate intravenously to start
  - Continue SCI or IMI regularly or IV infusion
  - Wean to simple analgesics
- Regional - epidural
- Monitor pain on a 0-10 scale
- Top-up before mobilisation
- Check for side effects
  - Respiratory depression
  - Sedation
  - Nausea/vomiting/itching
  - Confusion/hypotension
  - Urinary retention

Regional Anaesthesia

Occasionally, there may be a surgeon, an anaesthetist with only facilities for regional anaesthesia, and a patient requiring emergency abdominal surgery who cannot be moved to another hospital. Can anything be done with regional anaesthesia?

The options available are not ideal forms of anaesthesia for emergency abdominal surgery, but if resuscitation is carried out and the same principles followed as have been described above, possibilities include:

- Spinal anaesthesia
- Epidural anaesthesia
- Abdominal field block
- Para-vertebral block
- Splanchnic block

Spinal and epidural blocks have been described superbly in previous issues of Update (see Further Reading). They must not be used in patients who have not been fully resuscitated. Abdominal field block is best carried out by paravertebral intercostal block, first described by Sellheim in 1906, or paravertebral block, described by Kappis in 1912. Abdominal field block was first carried out by Schleich in 1899. Posterior splanchnic block was described by Kappis in 1919. These blocks have significant complications, and should only be attempted by those with excellent anatomical knowledge and technical skills.

Further Reading

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WORLD HEALTH ORGANIZATION HAEMOGLOBIN COLOUR SCALE
A practical answer to a vital need

Dr Michael Dobson, Oxford, UK

This article is based on WHO information regarding the Haemoglobin Colour Scale which is a simple, reliable and inexpensive tool developed by the WHO to screen for anaemia in the absence of laboratory-based haemoglobin measurement.

Anaemia is the most serious complication of iron deficiency and a significant cause of death. More than half of the pregnant women in developing countries suffer from anaemia. The accurate estimation of haemoglobin levels is an essential prerequisite in a variety of other health issues, such as trauma care, selection of blood donors, epidemiological studies, and general primary health care.

Detection and management of anaemia

The measurement of haemoglobin has long been recognized as fundamental in routine health checks, for the diagnosis and treatment of disease and, given the global incidence of anaemia, in public health care.

The measurement of haemoglobin in blood as an indicator of anaemia has traditionally relied on the services of a well-equipped clinical laboratory. Simple techniques do of course exist, but even these are relatively expensive and require commercial reagents, a good degree of technical skill and are not readily available in peripheral health clinics or at point of care for clinicians and midwives.

When laboratory facilities are not available, anaemia is usually diagnosed from clinical signs (pallor of the conjunctiva, tongue, palms and nail beds), although accurate interpretation of these signs depends a great deal on effective training and remains imprecise. However, in rural areas where anaemia is common and where appropriate prevention and treatment strategies may be most beneficial, an alternative, less sophisticated method is needed to screen for anaemia easily and economically.

Revisiting colour scales

The idea of a colour scale is not new. Tallqvist, among others, tried in vain as long ago as 1900 to substantiate the theory that the colour of a drop of blood could reliably indicate anaemia. The blood would be matched against predetermined shades of red, telling the health care worker whether the patient is anaemic and, if so, the severity of the condition. The colour printing technology and test-strip paper available at those times were such that the results were inaccurate and the concept shelved.

It has taken modern technology to perfect the material on which blood can be absorbed, and computerized spectrometric analysis to identify colours that can accurately match shades of haemoglobin at different concentrations.

Following many years of development by WHO, the Haemoglobin Colour Scale has been developed and produced as a simple and effective medical device for the accurate estimation of haemoglobin levels in blood.

How does it work ?

The scale (Figures 1) comprises a small card with six shades of red that represent haemoglobin levels at 4, 6, 8, 10, 12 and 14g/dl respectively. The device is simple to use:

- place a drop of blood on the test strip provided
- wait about 30 seconds
- match immediately the colour of the blood spot against one of the red shades on the scale.

This will indicate whether the patient is anaemic and, if so, the severity of anaemia in clinical terms (see diagram below). It will not identify, minor changes in haemoglobin during treatment, but rather assist in the management of any patient with suspected anaemia, e.g. to decide whether a patient may require a blood transfusion, or further laboratory tests.

Validation in the field

Since the early series of studies carried out by WHO in 1995 and the first published data describing the device in the same year, extensive testing and field trials have been carried out on the performance of the scale. An international validation study and recent published papers have confirmed its reliability when used in general health centres and antenatal clinics, and in blood transfusion centres for donor selection (see comprehensive bibliography).

Sensitivity and specificity of the Scale to screen for anaemia

For severe anaemia, the Scale shows a sensitivity of 95% and a specificity of 99.6%. To distinguish normal Hb levels from mild anaemia, the sensitivity and specificity are 98% and 86% respectively, results that are well above the reliability of any clinical measurement. Using the Hemocue (*see Update in Anaesthesia number 13*) as a reference, the Scale correctly identified 98% of anaemic donors in 2,800 potential blood donors.

Training

In a validation study, Most results were accurate to within 1-1.5g/dl. Further analysis showed that incorrect results were largely due to incorrect technique from a lack of training e.g. not waiting for 30 seconds, reading in a shadow or not having an adequate sized drop of blood.

The technique requires about 30 minutes of instruction for health workers to estimate haemoglobin to within 1g/dl, and assess levels of anaemia much more effectively than by traditional clinical diagnosis.

How much is it?

The Starter Kit with approved test strips for 1,000 tests will cost about US$ 20. This works out at less than 2c per test!

Haemoglobin Colour Scale starter kit contains:

Booklet of 6 shades of red;
Instructions for use;
Dispenser of 200 specially absorbent test strips in handy box,

Refill kits contain dispenser boxes of test strips only.
N.B. It is essential to use only the approved test strips provided. Packs of refills are readily available at low cost.

Summary

After several years of development and field trials, the Haemoglobin Colour is now in production and distribution, primarily to assist developing countries in the detection and management of anaemia. The device is not intended to compete with existing laboratory haemoglobinometry, but rather increase access to health technology for peripheral health services in resource-poor settings.

The clinical utility of the Scale has been demonstrated in the screening of blood donors for anaemia, malaria management, antenatal and child health programs, iron therapy control, in hookworm infection and in decisions to refer severely anaemic patients for hospital treatment. It will also be an extremely useful tool for anaemia checks anywhere, mainly for women and children suspected of being anaemic.

Use of this medical device does not depend on electricity or batteries and needs no maintenance. It is portable and the results are immediate. The training required is minimal, but nevertheless important.

The Haemoglobin Colour Scale is a practical answer to a vital need, a need contained in the first strategic direction of WHO: to reduce mortality and morbidity, particularly of the world's poor and marginalized populations.

For further information on how to procure the Haemoglobin Colour Scale, please contact Blood Transfusion and Clinical Technology, WHO, 1211 Geneva 27, Switzerland or direct from the manufacturers.

COPAK GmbH
Germany
Telephone 0049-40-713-1150
Fax 0049-40-712-24-94
e-mail info@copackservice.de

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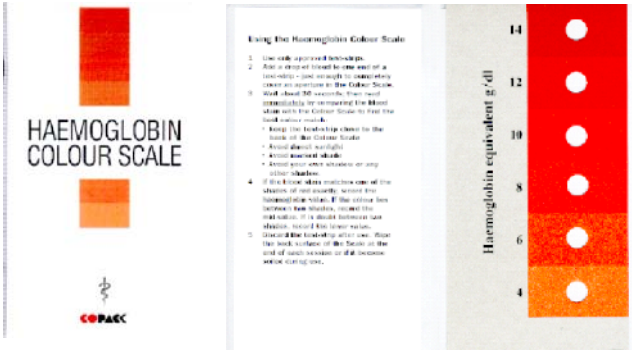

Figure 1

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