UPDATE IN ANAESTHESIA

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WORLD ANAESTHESIA

Editorial

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Welcome to Update in Anaesthesia issue 19!

Have you booked your place at the All Africa Anaesthesia Congress in Tunis 21-25 May 2005? The details of this great event are available at www.aaac2005.com We look forward to meeting many of our readers in Tunis.

We are pleased to let readers know that back copies of Update in Anaesthesia are available on the internet in several languages and can be accessed via the new World Anaesthesia website www.world-anaesthesia.org In addition compendium editions of Updates 6-12, and Updates 13-18 are available from www.talcuk.org for a small cost. TALC is also an excellent source of other educational material at very competitive prices.

As mentioned in Update 18, the Association of Anaesthetists of Great Britain and Ireland have produced an anaesthesia resource CDROM which is available free to readers of Update who have access to a computer. These can be obtained by emailing Michael.dobson@nda.ox.ac.uk It is planned to increase the number of different CDROMs available to anaesthetists in developing countries and information will become available about these on the World Anaesthesia website.

The Publications committee of the WFSA are keen to encourage anaesthetists with supplies of books and journals to share these by sending them to anaesthetists in less affluent parts of the world. If you would like to donate educational materials, or would like to receive these, please register with us via the World Anaesthesia website.

In April we plan to start a web based "Tutorial of the Week" on the World Anaesthesia website. The idea behind this is to produce a short anaesthesia based tutorial once a week for readers of Update. The tutorial can either be accessed via the internet, or received as an email. If you wish to receive the tutorial by email please email carol@world-anaesthesia.org and she will register you for when the scheme starts.

Lastly the costs of producing and distributing Update are generously paid for by the WFSA. We have a limited budget and last year could only produce one journal. If anyone is able to help with extra funds for our work the editorial board and our readers would be very grateful. We would also ask that readers who are able to access the electronic version of Update do not ask for a paper copy as it is much more economical to either access via the internet (free of charge) or request a CDROM instead (which also includes much more material!).

Happy 2005!

Iain Wilson
Editor

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LIFE THREATENING EXPLOSION OF OXYGEN REGULATOR.

Dr Joe Mellor, Consultant Anaesthetist., Leeds General Infirmary, Leeds. UK. Email: Joe.Mellor@leedsth.nhs.uk

Oxygen supports combustion. Chemistry students will have witnessed the re-ignition of a glowing splint in an atmosphere of 100% oxygen. Any flammable substance may become dangerous when exposed to an atmosphere of 100% oxygen and this effect is worsened either in the presence of high pressure or in the presence of heat. The following short report describes a life threatening incident that occurred during the handling of oxygen. It is written with the intention of demonstrating the danger we face when dealing with oxygen in the operating theatre.

The incident occurred in a 200 bed hospital in South East Asia. Two operating theatres were supplied with oxygen from two large oxygen cylinders situated in the hospital basement, a floor below the operating rooms. Each cylinder was connected to a pressure regulator converting the cylinder pressure, maximum 137 atmospheres, to pipeline pressure of 4 atmospheres. The two regulators were then connected to a pressure gauge and to a common pipeline, supplying the operating rooms upstairs.

Oxygen was supplied from one cylinder until it was nearly empty. At this point, the full cylinder was switched on and the old one replaced. (Figure 1)

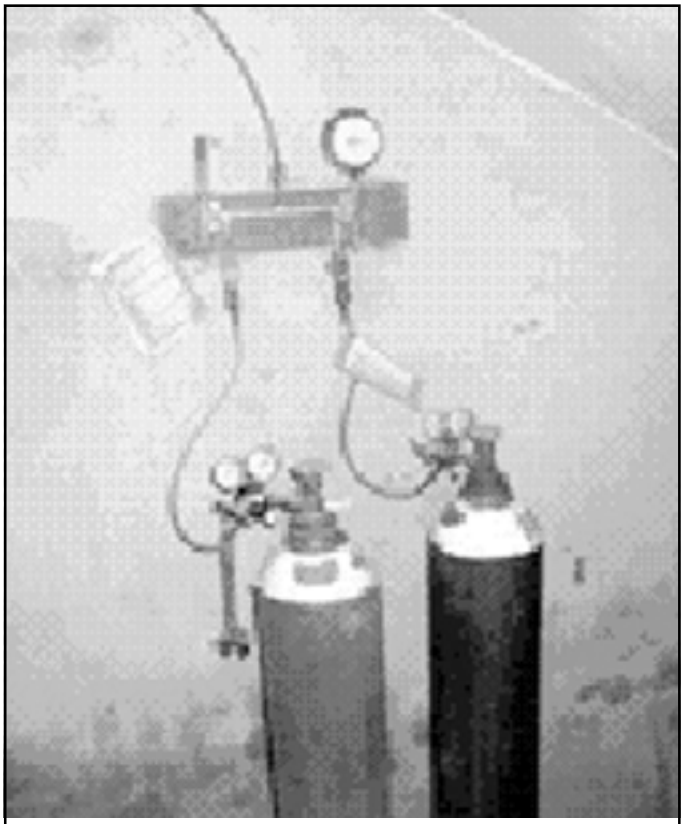

Figure 1: Cylinders

A close up view of the oxygen regulator is also shown. The model was a variable output type regulator but the point of discussion is relevant to the variable and fixed output types. (Figure 2)

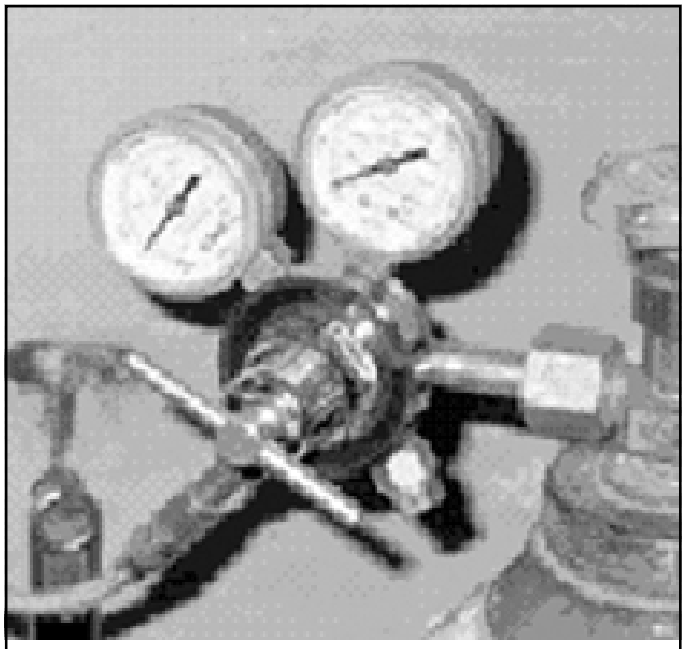

Figure 2: Oxygen regulator

An oxygen regulator was found to be faulty some time before the incident. It was sent to be serviced. The service was carried out by technicians who may have been unfamiliar with this equipment. They may have been unfamiliar with precautions needed when servicing oxygen regulators.

The oxygen regulator was returned and was attached to the top of a full cylinder of 100% oxygen. The cylinder was switched on and there was immediately an explosion, which completely destroyed the body of the regulator. The pressure gauges were thrown upwards with sufficient force to shatter them on the ceiling. The explosion was accompanied by a flash fire which burnt the anaesthetist who was changing the regulator. His shirt was burnt away and he sustained second degree burns to his trunk as well as superficial injuries from flying metallic debris. He sustained more serious injuries to his exposed arms. Fortunately, his burns were mostly second degree, with a small patch of third degree burning over his right wrist. See figure 3. Fortunately, the anaesthetist's face was spared and he suffered no burns to his airway.

Explosions in the operating theatre environment are not a new phenomenon. Explosive anaesthetic agents like ether are a well known risk. I believe the mechanism of this explosion is oil having been used as a lubricant on the pressure regulator or pressure gauge. The fact that oiling mechanisms that come in

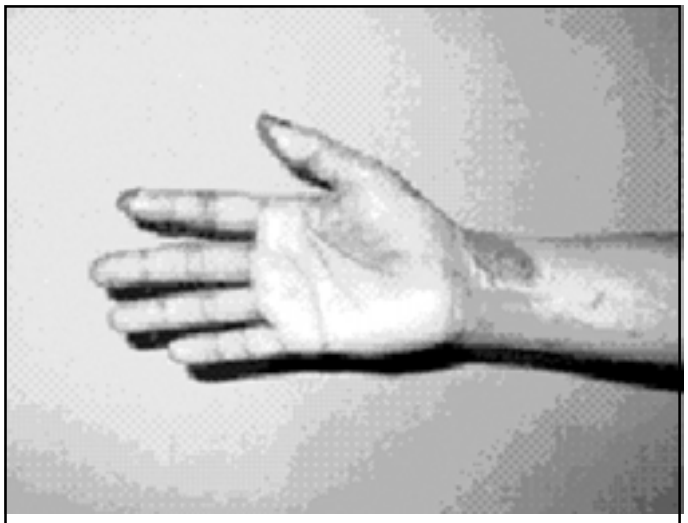

Figure 3: Burn

contact with high oxygen concentrations is dangerous is sufficiently well known that the gauges have warnings written on them. However, despite written warnings on the gauge, on questioning, it appears likely that oil was used in its maintenance.

Gas flowing through the mechanism of the regulator will have aerosolized the oil. The combination of high pressure, 100% oxygen and this aerosol will have produced an explosive mixture. It is hard to speculate on the mechanism that ignited this mixture to cause an explosion. Indeed oxidation and explosion may have occurred spontaneously in such conditions, without the need for a spark or similar stimulus.

This demonstrates a clear learning point:

Service of oxygen regulators and other anaesthetic apparatus, must only be carried out by those with adequate training. Oil, grease or flammable lubricants must never be used on any apparatus which may be exposed to a high concentration of oxygen.

PHYSICS IN ANAESTHESIA: THE FIBREOPTIC INTUBATING LARYNGOSCOPE

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Light normally travels in straight lines but there are circumstances in which the light-path is not straight. When we look in a mirror the light rays from our face hit the mirror and bounce back - this is called **reflection**. Reflection of light from shiny surfaces is seen everyday and is the first example of light not traveling in a straight line. The other is a bit more complicated. If you stand by a pond or river holding a stick and dip the end of the stick in the water, the stick appears to bend a little at the surface of the water. Of course the stick is still straight, and it is the light rays that have been bent. This type of light bending is called **refraction**.

Being able to bend light in these two ways means that it is possible to build a glass rod and force the light to travel down the inside of the rod. If the rod is very thin (called a fibre) it can be bent to go round a corner and the light will still travel in the rod even going round a fairly sharp bend. It is possible to build an instrument which contains a lot of these fibres and use the instrument to look round corners inside the body. The instrument is called a flexible fibrescope and this chapter looks at the physics of light bending and how a fibrescope works. Anaesthetists use flexible fibrescopes to look into the trachea and lungs and also to help put tracheal tubes in the right place.

Physics of Fibreoptic Light Transmission

- **Reflection**. When light hits a surface it bounces off it. The angle at which light bounces off is exactly the same as the angle at which it hits the surface. Put another way, the law of reflection state that 'the angle of reflection is the same as the angle of incidence' and this can be seen in figure 1.

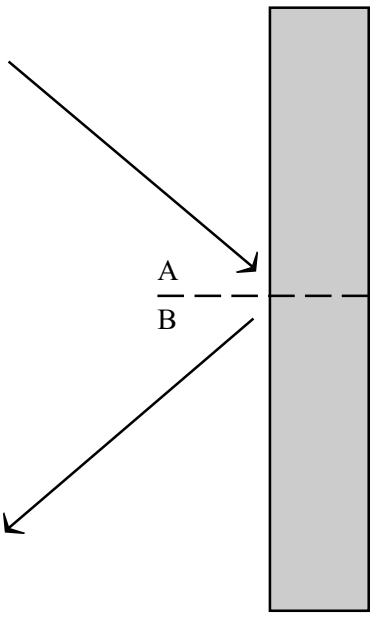


Figure 1: The angle at which the light hits the mirror is the same as the angle of the reflected light. Angle A is the same as Angle B.

- **Refraction (Snell's Law)**. Refraction is more complicated and concerns what happens to light when it is travelling in one substance (or medium) and hits another medium. The light can bend at the junction or interface of the two substances. When light passes from one medium, for example air, to another, for example glass or water, the direction that the light is traveling in changes. This is known as refraction. It happens because the speed of light varies in different mediums.

The law that describes how refraction of light occurs is named after a Dutch mathematician, Willebrord van Roijen Snell, who made it known in 1621. Rene Descartes, a French mathematician and philosopher, also described refraction in 1637, calling it the Law of Sines. They both realized there are two factors that determine how much the light bends at the junction between the two substances:

1. The nature of the substances. The speed of light is very fast but is different in different mediums. Each substance has a measure of this called the index of refraction. The **index of refraction** is the ratio of the speed of light in a vacuum to the speed of light in a given medium. Note that when we refer to the speed of light in general terms, what we are talking about is the speed in a vacuum such as space. The speed of light changes when it passes from one medium to another, for example from air to glass, causing it to change direction. The index of refraction for air is 1.0, for water 1.3 and for normal glass 1.6.

2. The **angle of incidence of the incoming ray of light** (shown by the symbol (θ in figure 2). In other words, the angle at which the light strikes the junction between two media, taken from a line that is at right angles to the junction.

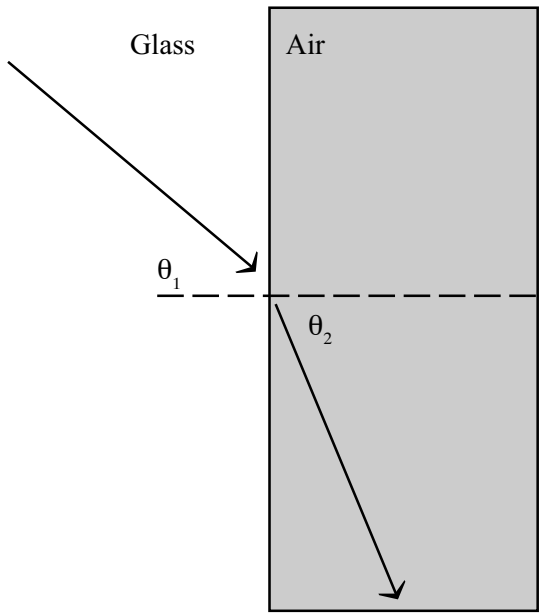


Figure 2. This demonstrates Snell's Law. In this example medium 1 has a refractive index greater than medium 2, such as is the case when light passes from glass to air.

The Critical Angle and Total Internal Reflection

Sometimes the bending of the light at the junction or interface is so great that the light appears to be reflected from the interface. The light has bounced back at the junction and doesn't pass through. This is called **total internal reflection** (figure 3).

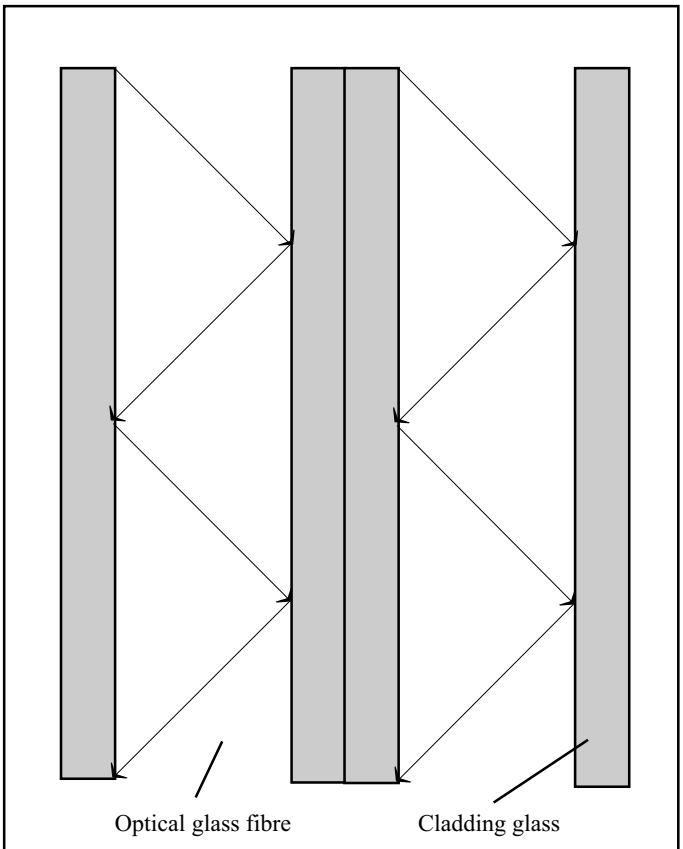


Figure 3. Light transmission, by total internal reflection, along parallel glass fibres.

Structure of The Glass Bundles Used in a Fibrescope

The glass fibres used inside fibrescopes are constructed so that light is able to pass within the glass fibre from one end to the other by total internal reflection.

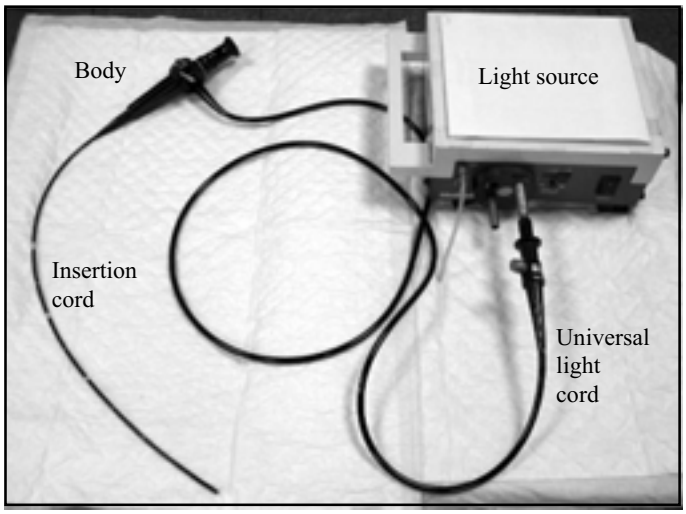
During manufacture glass is heated and stretched into very thin fibres. These are only 8-10μm in diameter. Each fibre is coated, or cladded, with a thin layer of glass (only about 1μm thick) which has a much lower index of refraction, ensuring that only total internal reflection of light takes place and preventing light passing between fibres (figure 3). These fibres are grouped together into flexible bundles containing several thousand fibres. Several bundles are then placed together to form the **image transmitting bundle**. This is also called the **viewing bundle**.

The total number of fibres in the viewing bundles varies from 36,000 to 85,000, depending on the size of the scope. The greater the number of fibres, the larger and clearer the image will appear. This is because each fibre, being very thin, will only transmit a small image. The final image is made up of all these small images added together, similar to the way an image appears on a television screen or digital camera. This explains why black dots appear on

the image when individual fibres or groups of fibres are broken.

Each fibre within the viewing bundle is arranged in a specific position, relative to the other fibres, throughout the length of the bundle. If the fibres were all jumbled up, so would be the image. A **coherent** bundle is one which will transmit an accurate and clear image and this is necessary for the **viewing** bundle.

If the fibres are not specifically arranged, then there will be just a random array of light seen at the eyepiece. The fibreoptic bundles that transmit light from the light source to the object, in order to illuminate it, are like this. That is because these bundles, known as the **light transmission bundles**, or **incoherent bundles**, only need to transmit white light. The fibres in the light transmission bundle are thicker than those in the viewing bundle, approximately 10-15 μm in diameter. There are also only about 6000 fibres in these bundles.



Basic Structure of the Fibrescope

Since the 1980's, manufacturers have made available sophisticated, well-constructed fibreoptic intubating laryngoscopes with a standard insertion cord length of 60 cm and a standard thickness of 4mm for adults, down to 2 mm thickness for small children. These allow narrow diameter tubes to be passed over the scope into the trachea.

The instrument has 3 main components:

The Body which has the following features:

- The **eyepiece**.
- The diopter ring, part of the eyepiece, which is used to focus the image.
- The lever, which controls the angulation near the tip of the scope.
- The working channel access port.

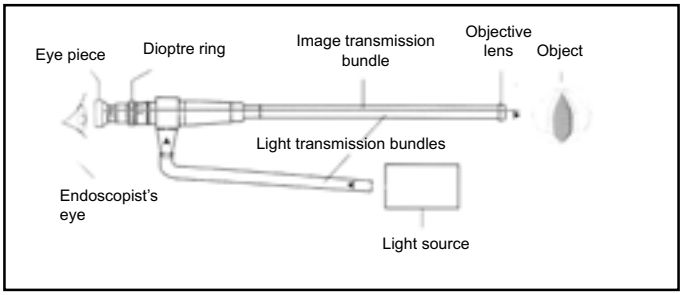
The Insertion Cord which contains

- The light transmission (viewing) bundle.
- The **objective lens**, situated at the tip of the scope, over the distal end of the viewing bundle.
- The light transmission bundles. There are usually two.
- The working channel: this can be used for suctioning secretions, injecting drugs, insufflating oxygen, to pass guide wires or biopsy instruments.
- The control wires. There are two of these. They extend from the lever on the handle to the tip of the scope.

All the components of the insertion cord are enclosed in a wire mesh. This is then covered by a waterproof plastic coating. Note that as the diameter of the insertion cord is reduced, so the size of the working channel is reduced, making it less useful, especially with regards suctioning of airway secretions.

The Universal Light Cord contains light transmission bundles, which transmit light from a l**ight-source** to the light transmission bundles in the insertion cord. The universal cord has a connector which plugs into the light-source. The light-source is a separate box that is operated by electricity. To make this system more portable, and for use in areas where electricity is not available, the universal cord can be replaced by a handle-shaped, battery operated light-source, attached to the body of the scope, as shown in the photograph. Often the ETO (ethylene oxide) cap is present on the ULC. This port does not need to be used normally.

Pathway of Light



- White light is transmitted from the light-source through the incoherent, light transmission bundles to the distal end of the instrument.
- This illuminates the object.
- Light from the object is reflected onto the objective lens.
- The objective lens focuses the light onto the distal end of the coherent, image transmitting bundle.
- Light travels by total internal reflection up the image transmitting bundle to the to the lens in the eyepiece.
- The image is focused onto the retina of the viewer's eye using the diopter ring, so that the image is clear.

Note: A camera can be attached to the eyepiece of the fibreoptic intubating laryngoscope, enabling the image to be seen on a television screen. This is a very useful aid to teaching fibreoptic technique and for demonstrating pathology of the upper airways to colleagues.

Practical Care of Fibrescopes

A flexible fibrescope is expensive and can be broken by poor handling. Handle it gently and do not knock, twist or bend the insertion cord or catch it in the door. The commonest cause of damage is catching the fibrescope between the lids of the carrying

case. The fibrescope should not be tightly coiled, and the distal bending section should not be bent by hand. After cleaning, the fibrescope should be kept in a cupboard supported by the control section so that the insertion tube is hanging straight down. This keeps it clean, allows it to dry out and keeps the insertion tube straight. It should not be stored in the travelling case.

After use in a patient, the fibrescope must be cleaned. The most important point is to immerse the whole scope in a bowl of warm water with a splash of detergent. Using a syringe, flush the working channel with 40-60 ml of this warm water to force out any blood or mucus. If possible, use a long channel cleaning brush passing this down from the control section until it emerges at the tip of the scope. The brushes are very narrow and prone to damage. Scrub the whole outer surface with a soft scrubbing brush to remove all mucus or blood from the external surface. Rinse off the detergent with ordinary water. It is much more important to wash the fibrescope in detergent than to place it in disinfectant.

The fibrescope must NOT be autoclaved or boiled. Heating above 50-60^{o}C will destroy the fibrescope. After manual cleaning with detergent, the fibrescope can be disinfected by placing in a cold chemical disinfectant solution for the appropriate time. The cheapest disinfectant is 2% activated glutaraldehyde and an immersion time of 20 minutes should kill most bacteria and viruses. Spores require much longer - possibly 2 hours. The fibrescope should not be immersed in any fluid for longer than 6 hours. After immersion, the fibrescope should be rinsed in sterile water before being hung up to dry. If no cold chemical disinfectant is available, wiping the outside and flushing the working channel with 70% alcohol will kill some viruses. The fibrescope should not be immersed in alcohol.

Further Reading

1. Airway Management, Principles and Practice. Benumof J L, Mosby-Year Book, 1996

2. Handbook of Difficult Airway Management. Hagberg C A, Churchill Livingstone, 2000

3. Practical Fibreoptic Intubation. Popat M, Butterworth Heinemann, Oxford, 2001

4. Fibreoptic Intubation. Hawkins N. Greenwich Medical Media, London, 2000

PREMEDICATION DRUGS USEFUL FOR CHILDREN

Dr Beth Newstead, Exeter, UK

Parents are often the best pre-medication" - G. Gordon MD

Routine sedative premedication is unnecessary for the majority of children, although a few patients will require this, often based around previous experience. Analgesia drugs are particularly useful when given preoperatively as the analgesic effect is present on awakening. Drugs to reduce the pain of venepuncture are commonly used.

Local Anaesthetic Creams

These creams are simply and easily applied and allow intravenous access in a relatively pain-free manner. The secret to success is correct application (see below).

Ametop (= topical amethocaine gel)

Ametop should be applied in a generous layer over veins suitable for cannulation (most commonly the dorsum of the child's hands). It should be applied to a minimum of 2 sites. The cream is covered with an occlusive dressing. For best results it should be applied 30-45 minutes prior to venepuncture. Its effect lasts for several hours (even when the cream is removed).

EMLA cream (= eutectic mixture of local anaesthetic: lignocaine and prilocaine)

EMLA cream is applied in a similar manner to that described above. It can be applied 1-5 hours prior to venepuncture. However, once the cream has been removed, its anaesthetic effect wears off very rapidly (within 20-30 minutes). It is reported to cause vasoconstriction and thus Ametop is often preferred if there is a choice. It is not suitable for use in children under 1 year.

Sedatives

Undergoing surgery can be a traumatic experience for children. Fear of pain and unpleasant procedures may cause significant upset. Younger children are unlikely to understand what is happening to them and are particularly likely to become distressed. Attempting to establish a rapport with the child, allowing patients into the anaesthetic room and topical local anaesthetics are all helpful strategies. However in a few cases the decision may be made to employ sedative medication. In particular this may be useful in children likely to undergo multiple operations/ procedures.

Benzodiazepines are the most commonly used sedative.

Ketamine has been suggested as an alternative pre-med in children. In low doses ketamine has hypnotic, analgesic and amnesic effects. Ketamine may be associated with emergence phenomenon in some children.

Drug	Route of administration	Dose
Ketamine	PO	7mg/kg
Ketamine	IM	2mg/kg

Drug	Route of administration	Dose	Comment
Midazolam	PO	0.5mg/kg	Mixed with fruit juice or Calpol (to mask taste). Acts within 15-30 min.
Midazolam	Intranasal	0.5mg/kg	Unpleasant for the child
Temazepam	PO	0.5-1.0mg/kg	

Analgesia

As with adults there has been a trend towards pre-emptive analgesia. If a child can be easily persuaded, then a combination of paracetomal and ibuprofen syrup given pre-operatively is very useful. If stronger analgesia is required (often in emergency patients) then opiates can be utilised. Intra-muscular injections should be avoided. If coercing a child to take medication is likely to cause upset then giving PR medication at the time of induction is an excellent alternative (but make sure the parents consent for this first).

A recent development in paediatric analgesia is the use of intra-nasal opiates. They work quickly, are generally well tolerated and avoid the need for intravenous access. A suitable dosing regime for intranasal diamorphine is shown below.

The child is weighed. The above chart is then used to work out the correct volume of saline to add to 10mg of diamorphine. 0.2mls of this solution is then drawn up into a 1ml syringe. The child is sat at 45 degrees and 0.1mls of the solution is squirted up each nostril.

Drug	Route of administration	Dose
Paracetamol	PO/PR	15-20mg/kg
Ibuprofen (over 7kg)	PO	5-10mg/kg
Diclofenac (over 1 year)	PO/PR	1mg/kg
Morphine	IM	200mcg/kg
Morphine (Oromorph = oral preparation)	PO	400mcg/kg

Weight of child (kg)	Volume of saline (ml)	Dose of Diamorphine (mg)
10	2.0	1.0
15	1.33	1.5
20	1.0	2.0
25	0.8	2.5
30	0.66	3.0
35	0.57	3.5
40	0.5	4.0
45	0.44	4.5
50	0.4	5.0

ALL AFRICA ANAESTHESIA CONGRESS

Dear Colleague
Greetings from Tunisia, a friendly country with a great history and legendary hospitality.

I am honored to invite you to All Africa Anaesthesia Congress (AAAC 21 - 25 MAY 2005) at which leading anaesthesiologists will focus on the advancement of anesthesia and intensive care around the world.

The congress will be held in the delightful venue of Yasmine Hammamet Harbor, beside the Mediterranean Sea. Special accommodation rates and excursions will be available for you over the congress period.

This will be the Third All-African Anaesthesia Congress, organized by the World Federation of Societies of Anaesthesiologists (WFSA), the Maghrebian Federation of Societies of Anaesthesiologists (FSMAR) and the Tunisian Society of Anaesthesia, Analgesia and Intensive Care (STAAR).

We have developed a comprehensive scientific program with workshops and symposia on exciting topics ranging from Pain, Emergency medicine, Anaesthesia, Critical Care, Research and Education to Ethical issues in ICU and Anaesthesia.

We will have over 60 speakers from 30 countries sharing their ground-breaking discoveries in these research areas with you. You will have the golden opportunity to meet our distinguished speakers.

I urge you to take this opportunity to register early, and encourage other Anaesthesiologists to do the same. Our congress secretariat will be pleased to assist with information on the congress packages.

With so many exciting programs and excellent speakers, I am certain that you will acquire state-of-the-art knowledge that will make a substantial difference in your professional life and patient outcomes. I am confident that this meeting will be a great learning experience, which will contribute extensively to your sphere of work.

Please visit us at http://www.aaac2005.com/ to view and download a brochure for your reference. If you wish to submit an abstract, please do so before the 31th of January 2005. My team and I look forward to welcoming you in Hammamet from 21 - 25 may 2005.

Yours sincerely

Dr Mohamed Salah Ben AMMAR
Chairman of the congress

TEACHING ANAESTHESIA IN THE OPERATING THEATRE

Kester Brown, Royal Childrens Hospital, Melbourne, Australia

The prime function of the anaesthetist (anesthesiologist) in the operating theatre is to care for the patient. This involves vigilant monitoring, adjustment of the anaesthetic and fluid and blood replacement as required. The anaesthetist should also follow the progress of the operation, watching for any untoward events which might be detrimental to the patient.

Teaching in the operating theatre has two components – practical and theoretical. There has to be a teacher and a trainee (or student). Good practical training requires thorough instruction by the teacher and all trainees should be supervised closely during the early part of their training so that they learn good habits and hopefully how to perform their tasks efficiently and safely. This puts an onus on the teacher to be active and to be present, not out having coffee or on the phone.

There are several environmental factors which differ from teaching outside the operating theatre. The most important is that **someone must be watching** the patient and the monitors. This means that one may have to forego continuous eye contact with the person with whom you are talking. If masks are worn, half the face is covered and some of the facial expression is hidden. These are important components of normal communication with others.

The surgeon may prefer a quiet environment so discussion should be conducted in low tones which are not disturbing to others. The anaesthetist must also be responsive to comments from the surgeon and to audible monitors. The pulse oximeter which changes tone when the saturation drops is a very useful warning device, but one must be aware of the tone even while talking. It is inappropriate to be chatting when tense situations are occurring. Experienced anaesthetists learn to concentrate more acutely at key times during operations such as when the chest is being finally closed during a thoracotomy or when the neurosurgeon is working around the brain stem.

A survey to which 1600 anesthetists responded indicated that 90% taught. This is a high proportion. Many will not have had instruction on how or what to teach. Some people are successful, often using their personal experience as the basis of what they can convey. We all have experiences which we can share, and some of these can be the basis of what we can teach.

Interactive teaching where there is two way discussion is more useful to the trainee. Questions can be asked which help the teacher to find out what the trainee does or does not know and therefore where the discussion can be most usefully directed. Sometimes concepts can be clarified and basic principles explained to improve understanding of why certain things are done or happen. An assessment of what has been learned can be made by asking the student to go over points that have been taught. This also re-enforces the points.

Practical teaching starts at the induction. How to handle the patient – be friendly when they arrive. Talk to him or her and try to create a relaxed atmosphere. This is mostly taught by example but can be discussed and stressed verbally. An anxious patient who has not received premedication may have an increased cardiac output and redistribution of blood flow to muscle from the sympathetic response. This is the reason why a larger dose of induction agent is needed or it takes longer to render a child unconscious when giving an inhalational induction. The redistribution of cardiac output with anxiety and hypovolaemia are very useful topics which can be discussed because they are relevant and it may save a patient's life if the trainee or student learns that the brain and heart receive relatively more of the depressant drugs when they are hypovolaemic, so less should be given in increments until the desired effect is reached.

Some practical procedures have to be taught during induction - intravenous cannulation, ventilation with the mask, insertion of an endotracheal tube or laryngeal mask airway. **Ergonomic analysis of the techniques**, which are described to the trainee in steps, makes it much easier to learn them. How and where to insert the cannula must be considered. A position which is easily accessible to the anaesthetist during anaesthesia must be chosen. How to hold the needle, insert it and then, when flashback of blood occurs, to advance the cannula into the vein should be demonstrated and the steps described. The last point is important in small children otherwise the cannula may not be in the vein when the needle is removed because the tip reaches beyond the end of the cannula. With very small cannulae kinking may occur when strapping is applied. To avoid this the needle may be left in place until the first tape is secure. Intra-arterial and central venous cannulation also require careful instruction about the techniques.

It is important to teach how to maintain an airway with a mask. Too often today an LMA is inserted and trainees cannot maintain an airway adequately with a mask. In children, an oropharyngeal airway is not often needed if the neck is extended (this usually causes the mouth to open), the mouth is opened, and then the mask is laid on the chin and then on to the face. The thumb and index finger push the mask on to the face to make an airtight fit and the little finger is used to pull the angle of the mandible forward keeping the pharynx open. This does not require tight grasping which strains the hand muscles. Gentle application of the forces in the right directions can achieve it without causing fatigue.

The most important point in endotracheal intubation is to make sure that the tube is inserted from the right hand corner of the mouth so that its tip can be seen going between the vocal cords. If this is done inadvertent oesophageal intubation is avoided. This is a serious cause of morbidity and even mortality. Check that both sides of the chest are moving and that there is air entry.

The capnograph will show a normal respiratory pattern and CO_2 level if it is in the trachea. This is a major reason why the capnograph has become a recommended monitor in countries where it can be afforded.

Regional anaesthesia and nerve blocks can be taught by demonstration or by first going through the anatomy and the layers that the needle will pass through before beginning the procedure and then guiding the trainee through the steps as it is performed. It is usually better to demonstrate first indicating the steps and then letting them do the next one. The problem is that the teacher may not have a second opportunity with that trainee. To learn the trainees must be taught and understand exactly what they are trying to do and then be guided through the procedure. Again the stepwise approach is best. Depth can be determined by knowing what layers the needle must pass through to reach the nerve. The key points are that fascia and aponeurosis can be felt by a short bevelled needle as a "pop" or loss of resistance and, secondly, that it is difficult to inject into muscle. If a nerve lies deep to a muscle there will be resistance to injection when gentle pressure is placed on the plunger of the syringe but it becomes easy to inject as the needle emerges into the space deep to the muscle where the nerve may be traversing.

Anaesthetists vary in how easily they can hand over technical procedures to learners. Experienced anaesthetists, who are relaxed and confident that they can sort out problems should they arise, are usually more willing to let others try than those who are tense and don't like to feel that they are not in complete control. It is a personal matter but trainees have to realize that anaesthetists vary in how much responsibility they pass on. As the trainee becomes more competent the trainer will allow him/her to do more.

When all is prepared the patient must be positioned for the operation. Often this is supine but sometimes special positioning is necessary for the surgeon to gain access to the operative site. Attention to detail is important and again the teacher must explain the steps – avoidance of pressure areas, having the intravenous where it is accessible and will run well, having the blood pressure cuff on the other arm, and avoiding nerve injuries. It is easy to just put the patient on the table and not point out these details but if the trainee is not made aware he/she may not think of them and eventually a complication may occur which could have been avoided. In more complex procedures such as neurosurgery, patients with an arterial line for blood pressure monitoring should have the transducer at head level so that it is measuring the pressure there. This is particularly important if the patient is positioned head up.

Usually, a trainee can become a good, practical anaesthetist if well taught provided they can develop the necessary technical ability. The onus is also on the teacher to be present to teach. There are a few people who do not have the technical aptitude for the specialty. They should be guided to a field where manual dexterity is not important.

Once the patient is on the table, all the monitors are attached and the mode of ventilation can be adjusted. There is more to squeezing the reservoir bag or putting patients on the ventilator than people sometimes realize. Prolonged inspiration can inhibit venous return, which can have an adverse effect particularly if the patient is somewhat hypovolaemic. Too short an inspiratory phase may produce uneven ventilation with V/Q mismatch. Usually a 1:2 inspiration : expiration ratio is used aiming to keep the mean intrathoracic pressure low.

Once a stable anaesthetic state has been reached more theoretical teaching can take place. This usually begins with discussion about the patient and operation being done so that all the issues can be clarified. Then one can go on to related or unrelated topics – the important applications of basic sciences to anaesthesia, other operations, or even philosophy or the cost of the anaesthetic! Significant savings can be made if people are aware of the costs of the drugs and equipment they use and try to be more careful and economical.

Sometimes the supervisor does not feel like teaching. He/she may be tired or not be a readily communicative person but if the trainee shows some interest and enthusiasm it is easier for the supervisor to be activated. An enthusiastic teacher can pass on a considerable amount of information in a short time but one must remember that the student may not have an unlimited capacity to remember it all if too much information is provided. It may be useful, having covered a dozen or so pieces of information, to run over them again briefly so that the trainee's memory is reinforced. It may then be appropriate to go on to less demanding discussion on another topic.

Occasionally there is a mismatch between teacher and trainee. The first may not be a great teacher and may not be up with the latest information and the trainee may be very bright. The teacher must just say they do not know if asked about something beyond their knowledge. This same teacher may be able to teach a few good practical points from their experience and should concentrate on them. It should not develop into a matter of conflict or an adverse view of the student because the teacher feels inferior. One brilliant trainee was labelled as troublesome by his trainers because they could not answer his complex questions. Turn the situation around and get the student to teach the teacher. Teachers often learn from their trainees. Continued learning from ideas brought up by trainees can be stimulating and be one of the joys of teaching.

At the conclusion of anaesthesia there is another period of heightened activity when practical matters become more important. If a complication like laryngeal spasm occurs, it is a good time to teach how to handle it. First apply continuous positive pressure with oxygen. It must be continuous so that any slight lessening of the spasm will allow oxygen to enter the lungs. It is better for a trainee to experience complications with an experienced teacher who knows how to handle them because it is less stressful and they learn what to do in practice. The spasm will usually break before the patient comes to harm but sometimes a small dose of suxamethonium (0.3 mg/kg) can be used to relieve the spasm. Larger doses lead to longer periods of paralysis. It is not usually necessary to re-intubate and this may lead to a recurrence of the situation.

When the patient has been transferred to the trolley they should be placed on the side unless there is a reason not to. Even at this stage teaching can continue. Why on the side? Which side – the

one that will leave them facing the nurses if complications are to be minimized. Place the upper hand under the jaw to keep the neck extended and the airway open. During transfer one can assess that the patient is breathing by observing the condensation in the oxygen mask. They are all useful, practical points.

Teaching in the operating theatre can only occur if there is someone present to teach. Beginners should always be with someone who can teach them, hopefully good habits.

Most practical teaching occurs in the operating theatre. It usually takes longer to induce anaesthesia when teaching is in progress but we should still try to make the trainees think of how they can do things in the most efficient way so that delays are minimized. It is also good practice to work in the ergonomically most efficient way and to think about how this is achieved. Too often this is neglected but it is essential if one is going to develop into an efficient and careful anaesthetist. When the teacher analyses the techniques it makes it easier for trainee or student to learn because they know exactly what they have to do to achieve their objective.

One must always remember that while teaching, one's primary responsibility is the care of the patient.

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CALCIUM HOMEOSTASIS

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Calcium is an essential ion within the human body. The maintenance of a constant free ionised calcium concentration is biologically important for the function of excitable tissues. Abnormalities in serum calcium values may have profound effects on neurological, gastrointestinal and renal function. Normal calcium concentrations are maintained as a result of tightly regulated ion transport by the kidneys, intestinal tract and bone. This is mediated by calcaemic hormones, in particular parathyroid hormone and the active form of Vitamin D. Changes in calcium transport resulting in movement into or out of the extracellular fluid will lead to hypercalcaemia, respectively. In this article the mechanisms responsible for calcium homeostasis will be reviewed.

Calcium balance

Calcium is an important nutrient. The daily intake is approximately 1000mg/day, about the amount of one litre of milk. The adult human body contains approximately 1100g (27.5mol) of calcium. 99% of the calcium is in bone. Blood calcium levels are normally 9-10.2mg/dL (2.25-2.55mmol/L). Of the total amount, 50% is free ionised calcium, 10% is combined with various anions (including bicarbonate, citrate, phosphate, lactate and sulphate) and the remaining 40% is bound to serum proteins mainly albumin. Free ionised calcium is the physiologically important component of the total calcium. In plasma, the ionised calcium concentration is normally maintained within a tight range (1.0-1.25mmol/l).

Intestinal absorption

30-80% of ingested calcium is absorbed, primarily in the upper small intestine. Absorption is related to calcium intake. If intake is low, active transcellular calcium transport in the duodenum is increased and a larger proportion of calcium is absorbed by the active process compared with the passive paracellular process that occurs in the jejunum and ileum.

Vitamin D is important for the active process. Active calcium transport depends on the presence in the intestinal cell of calbindin D9K, the biosynthesis of which is totally dependent on vitamin D. Passive absorption in the jejunum and ileum predominates when dietary calcium intake in adequate or high.

Calcium reaching the large intestine is absorbed by active and passive processes. Usually, no more than 10% of total absorption takes place in the large intestine, but this site becomes nutritionally important in conditions of significant small bowel resection.

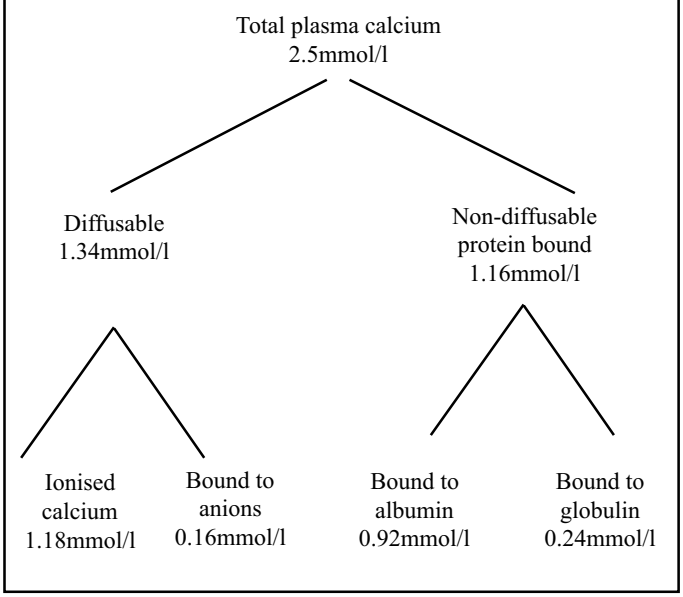
Calcium absorption I inhibited by phosphates and oxalates because these anions form insoluble salts with calcium in the intestine.

Physiological functions of calcium

Calcium plays a central role in a number of physiological processes that are essential for life. Calcium is necessary for several physiological processes including neuromuscular transmission, smooth and skeletal muscle contraction, cardiac automaticity, nerve function, cell division and movement, and certain oxidative processes. It is also a co-factor for many steps during blood coagulation. Intracellular calcium is involved as a second messenger in many intracellular responses to chemical and electrical stimuli and required by many enzymes for full activity. Many different calcium binding proteins have been described, but the two with well established functions are troponin and calmodulin. Troponin is involved in muscle contraction, whereas calmodulin causes configurational changes to proteins and enzyme activation.

Intracellular calcium levels are much lower than the extracellular, due to relative membrane impermeability and membrane pumps employing active transport. Calcium entry via specific channels leads to direct effects, e.g. neurotransmitter release in neurones, or further calcium release from intracellular organelles, e.g. in cardiac and skeletal muscle.

Figure 1: Distribution of calcium in normal human plasma



Influences on calcium concentrations

Total plasma calcium values vary with the plasma concentration. Since a significant proportion of calcium in the blood is bound to albumin, it is important to know the plasma albumin concentration when evaluating the total plasma calcium. In general, 0.2mmol/L must be added to the total calcium concentration for each 1g/dL decrease in albumin concentration from the normal 40g/dL. However, this relationship between albumin and calcium is less reliable in critically ill patients. Ionized calcium increases with acidosis, and decreases with alkalosis. Therefore, for each 0.1 decrease in pH, ionised calcium rises by about 0.05mmol/L. In order to ensure accurate measurement of calcium concentrations, blood should be taken without a tourniquet, and without hyper- or hypoventilation.

Regulation of calcium homeostasis

Three principal hormones are involved in calcium homeostasis, acting at three target organs, the intestine, bone and kidneys:

1 Vitamin D

Vitamin D is a group of closely related sterols produced by the action of ultraviolet light. Vitamin D3 (cholecalciferol) is produced by the action of sunlight and is converted to 25-hydroxycholecalciferol in the liver. The 25-hydroxy-cholaecalciferol is converted in the proximal tubules of the kidneys to the more active metabolite 1,25-hydroxy-cholaecalciferol. 1,25-hydroxychlecalceriferol synthesis is regulated in a feedback fashion by serum calcium and phosphate. Its formation is facilitated by parathyroid hormone.

The actions of Vitamin D as follows:

1. Enhances calcium absorption from the intestine
2. Facilitates calcium absorption in the kidney
3. Increases bone calcification and mineralization
4. In excess, mobilises bone calcium and phosphate

2. Parathyroid hormone (PTH)

Parathyroid hormone is a linear polypeptide containing 84 amino acid residues. It is secreted by the chief cells in the four parathyroid glands. Plasma ionized calcium acts directly on the parathyroid glands in a feedback manner to regulate the secretion of PTH. In hypercalcaemia, secretion is inhibited, and the calcium is deposited in the bones. In hypocalcaemia, parathyroid hormone secretion is stimulated. The actions of PTH are aimed at raising serum calcium.

1. Increases bone resorption by activating osteoclastic activity
2. Increases renal calcium reabsorption by the distal renal tubules
3. Increases renal phosphate excretion by decreasing tubule phosphate reabsorption
4. Increases the formation of 1,25-dihydrocholecalciferol by increasing the activity of alpha-hydroxyls in the kidney

A large amount of calcium is filtered in the kidneys, but 99% of the filtered calcium is reabsorbed. About 60% is reabsorbed in the proximal tubules and the remainder in the ascending limb of the loop of Henle and the distal tubule. Distal tubule absorption is regulated by parathyroid hormone.

3. Calcitonin

Calcitonin is a 32 amino acid polypeptide secreted by the parafollicular cells in the thyroid gland. It tends to decrease serum calcium concentration and, in general, has effects opposite to those of PTH. The actions of calcitonin are as follows:

1. Inhibits bone resorption
2. Increases renal calcium excretion

The exact physiological role of calcitonin in calcium homeostasis is uncertain.

The calcium-sensing receptor (CASR)

This receptor has recently been cloned. It is a G protein-coupled receptor that plays an essential part in regulation of extracellular calcium homeostasis. This receptor is expressed in all tissues related to calcium control, i.e. parathyroid glands, thyroid C-cells, kidneys, intestines and bones. By virtue of its ability to sense small changes in plasma calcium concentration and to couple this information to intracellular signalling pathways that modify PTH secretion or renal calcium handling, the CASR plays an essential role in maintaining calcium ion homeostasis.

Bone and calcium

The calcium in bone exists in two forms: a readily exchangeable pool and a much larger reservoir of stable calcium, which is about 0.5 to 1% of the total calcium salts and is the first line of defence against changes in plasma calcium. It provides a rapid buffering mechanism to keep the serum calcium ion concentration in the extracellular fluids from rising to excessive levels or falling to very low levels under transient conditions of excess hypoavailability of calcium. The other system is mainly concerned with bone remodelling by the constant interplay of bone resorption and deposition, which accounts for 95% of bone formation.

Effects of other hormones on calcium metabolism

Glucocorticoids lower serum calcium levels by inhibiting osteoclast formation and activity, but over long periods they cause osteoporosis by decreasing bone formation and increasing bone resorption. They also decrease the absorption of calcium from the intestine by an anti-vitamin D action and increased its renal excretion. The decrease in serum calcium concentration increases the secretion of parathyroid hormone, and bone resorption is facilitated. Growth hormone increases calcium excretion in the urine, but it also increases intestinal absorption of calcium, and this effect may be greater than the effect on excretion, with a resultant positive calcium balance. Thyroid hormones may cause hypercalcaemia, hypercalciuria, and, in some instances, osteoporosis. Oestrogens prevent osteoporosis, probably by a direct effect on osteoblasts. Insulin increases bone formation, and there is significant bone loss in untreated diabetes.

Key points in calcium homeostasis

- Calcium homeostasis is regulated by three hormones, parathyroid hormone, vitamin D and calcitonin. The free, ionised calcium concentration is physiologically important for the functions of excitable tissues such as nerve and muscle.
- Parathyroid hormone increases plasma calcium by mobilising it from bone, increases reabsorption from the kidney and also increases the formation of 1, 25-dihydrocholecalciferol.
- 1,25-dihydrocholecalciferol increases calcium absorption from the intestine, mobilises calcium from the bone and increases calcium reabsorption in the kidneys
- Calcitonin inhibits bone resorption and increases the amount of calcium in the urine, thus reducing plasma calcium
- The calcium-sensing receptor (CASR) plays an important role in regulation of extracellular calcium.

Clinical Implications for the Anaesthetist
Perioperative period

Dysfunctional states

Any abnormalities in serum calcium should be corrected pre-operatively. The main risk in anaesthetising patients with either hypo or hypercalcaemia is cardiac dysrhythmias.

Hypocalcaemia

Hypocalcaemia may present with acute symptoms or be asymptomatic. Clinical signs include tetany, carpopedal spasm and laryngeal stridor. It may occur in hypoparathyroidism, vitamin D deficiency, phosphate excess and acute pancreatitis. Hypocalcaemia may lead to cardiac dysrhythmias, decreased cardiac contractility, causing hypotension, heart failure or both. Electrocardiographic changes include prolongation of the QT interval. Hypocalcaemia may be accompanied by changes in magnesium concentrations.

Hypocalcaemia can occur following rapid administration of citrated blood or lavage volumes of albumin and in alkalosis caused by hyperventilation. Transient hypocalcaemia may also be seen following heparin, protamine or glucagons administration.

Acute hypocalcaemia can also occur in the immediate post-operative period, following removal of the thyroid or parathyroid glands. It may present as laryngospasm and re-intubation of the trachea may be required. Administration of intravenous calcium is needed to occur acute hypocalcaemia.

Hypercalcaemia

Hypercalcaemia may present with renal problems, polyuria and polydipsia, neuropsychiatric disorders, nausea, vomiting and peptic ulceration. The cardiovascular effects include raised blood pressure, a shortened Q-T interval and dysrhythmias.

Causes of hypercalcaemia include hyperparathyroidism, malignancy, drug therapy such as thiazides and lithium, and immobilisation. Specific treatment is aimed at the cause, but it may also be necessary to decrease calcium levels by increasing excretion and decreasing bone resorption. Frusemide, rehydration, calcitonin and intravenous phosphate buffers can be used to decrease serum calcium.

Neuromuscular transmission

Calcium plays an important role in neuromuscular transmission and muscle contraction. The interaction of calcium with muscle relaxants is complex and unpredictable. Although calcium facilitates the release of acetylcholine from the motor nerve terminal, it also stabilizes the post-junctional membrane. Overall, response to non-depolarising muscle-relaxants is potentiated by both hypo and hypercalcaemia.

Magnesium sulphate, used for the treatment of pre-eclampsia and eclampsia may cause muscle weakness by inhibiting the release of acetylcholine from the nerve terminal. Intravenous calcium will antagonize this effect.

Many antibiotics such as aminoglycosides, polymyxins, tetracyclines, lincomycin and clindamycin cause potentiation of neuromuscular block by nondepolarising muscle relaxants. Several mechanisms have been postulated to explain the variety of antibiotics that can cause such a block. One mechanism is thought to be an inhibition of the pre-junctional release of acetycholine, which can be reversed by administering calcium. This is especially useful in the case of aminoglycoside antibiotics.

Massive blood transfusion

During massive blood transfusion, hypocalcaemia can occur due to binding of calcium by citrate preservative in the stored blood. Clinically significant hypocalcaemia resulting in dysrythmias and hypotension does not occur in normal situations unless the transfusion rate exceeds one unit every five minutes. The citrate in the transfused blood is metabolised in the liver. Patients with hepatic dysfunction or hypothermia may require calcium infusion during massive transfusion.

Malignant hyperthermia

Malignant hyperthermia is a rare, autosomal dominant disorder, characterised by an acute hypermetabolic reaction caused by exposure to succinylcholine and volatile agents. Clinical features include unexplained tachycardia, hypercapnia, skeletal muscle rigidity, labile blood pressure, cyanosis, mottling of the skin and high body temperature.

The basic abnormality is an increase in cytoplasmic calcium ion concentration. The ryanodine receptor is a calcium efflux channel located on the sarcoplasmic reticulum. It modulates calcium release from channels in the sarcoplasmic reticulum. Abnormalities in the structure and function of this receptor are thought to be involved in the pathogenesis of malignant hyperthermia. Increased cytoplasmic calcium concentration results in prolonged actin and myosin interaction and irreversible contracture. This leads to increased O_2 consumption and CO_2, production. Dantrolene sodium is the drug of choice in the treatment of malignant hyperthermia and it acts by inhibiting calcium ion release from the sarcoplasmic reticulum.

The role of calcium cardiopulmonary resuscitation (CPR)

Calcium plays a central role in cardiac contraction. In the past, it was used as an inotropic agent during cardiopulmonary resuscitation (CPR). There is no scientific evidence to suggest that calcium has any benefits in the treatment of ventricular fibrillation or asystole. On the contrary, there is evidence that high plasma concentrations achieved following intravenous calcium administration during CPR could have deleterious effects on ischaemic myocardium and may delay cerebral recovery. It has been shown that calcium which accumulated excessively in the myocardium during arterial reperfusion after a period of relative ischaemia, led to cell death. Calcium is no longer recommended for universal management of CPR. Calcium is only indicated in CPR if there is:

- Severe hypocalcaemia
- Hyperkalaemia
- Myocardial depression resulting from calcium channel blocking drugs

Conclusion

In summary, calcium has an important physiological role in the conduct of anaesthesia. Meticulous attention should be paid to maintain serum calcium within the physiological limits and to treat any abnormality resulting from calcium imbalance.

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SELF ASSESSMENT SECTION- Multiple Choice Questions

Dr Beth Newstead, Exeter, UK

Please answer True or False to the following statements

1. With regards to fasting (T or F):

a. Clear fluids will usually empty from an adult stomach in 3-4 hours
b. Solids will usually empty from the stomach in 6 hours
c. Milk empties from the stomach at the same rate as other fluids
d. ASA guidelines recommend a minimum fast of 4 hours for breast milk
e. At least 100mls of gastric fluid needs to be aspirated to cause pulmonary damage

2. The following apply to pre-operative steroids:

a. 10mg prednisolone is equivalent to 40mg hydrocortisone
b. A patient on a maintenance dose of 6mg prednisolone requires additional intra-operative steroids
c. It is estimated that adults secrete 75-100mg of cortisol in response to a major surgical procedure
d. 10mg prednisolone is equivalent to 2mg dexamethasone
e. For a patient who is on 12mg prednisolone daily, a suitable dose of intra-operative hydrocortisone for a hernia repair is 100mg

3. With regard to Aortic Stenosis:

a. Severe aortic stenosis will always be symptomatic
b. A gradient of >80mmHg across the aortic valve is considered to be severe aortic stenosis
c. Spinal anaesthesia is safe in patients with aortic stenosis
d. With increasing severity of aortic stenosis, the louder the murmur becomes
e. If a vasoconstrictor is required in a patient with aortic stenosis, ephedrine is the agent of first choice

4. With regards to Trans-urethral resection of the prostate (TURP):

a. Most TURP surgery is done under a general anaesthetic
b. TUR syndrome is estimated to occur in 1-2% of cases
c. Treatment of TUR syndrome is with rapid correction of the hyponatraemia
d. Severe blood loss in TURP occurs in <1% of cases
e. Most patients will require no routine pre-operative investigations

5. The following are true of Suxamethonium:
a. Suxamethonium is a non-depolarising muscle relaxant
b. Suxamethonium is metabolised by plasma cholinesterase
c. Suxamethonium causes a rise in potassium of 1mmol/Litre
d. Suxamethonium commonly causes tachycardia in children
e. Approximately 10% of the population have an atypical gene coding for cholinesterase and will therefore have a prolonged neuromuscular block

6. The following are risk factors for laryngospasm:
a. Hypercalcaemia
b. Thyroid surgery
c. Gaseous induction
d. Tonsillectomy
e. Haemorrhoid surgery

7. The following are true on the subject of burns:
a. The commonest cause of death following a burns injury is smoke inhalation
b. Full-thickness burns are more painful than partial thickness burns
c. Prophylactic antibiotics should be given to all patients with >30% burns
d. The Parkland formula (used to guide fluid replacement in burns patients) is as follows: 10mls fluid per % burn per kg of weight
e. A patient with signs of airway compromise should be intubated early

8. The following are contraindications to a Bier's block:
a. Raynaud's disease
b. Hypertension (systolic > 200)
c. Age > 80
d. Crush injury to the arm
e. Ischaemic heart disease

9. The following apply to blood product transfusion:
a. Blood transfusion is not indicated if the Hb >10g/dl
b. The dose of FFP is 20ml/kg
c. FFP should be used within 4 hours of thawing
d. If a patient has been group and saved, it will take 45 minutes for a full cross-match
e. Cryoprecipitate contains high levels of fibrinogen

10. The following are true of spinal anaesthesia
a. The spinal cord ends at L2-L3
b. Injection should be at the level of L3-L4
c. Previous back surgery is an absolute contraindication to spinal anaesthesia
d. Heavy bupivicaine gives a lower block than plain bupivicaine
e. The incidence of neurological damage following a spinal is 6-7 per 10,000

11. With regards to positioning on the operating table:
a. In the head-down position, the patient may prove more difficult to ventilate
b. Patients should be intubated if put in the prone position
c. The head-up position may lead to an increase in blood-pressure
d. In the supine position: if one arm is abducted the head should be turned in the opposite direction
e. A potential complication of the lithotomy position is peroneal nerve damage

12. With regards to Paediatric anaesthesia:
a. The formula for calculating a child's weight is (age + 4) multiplied by 4
b. A size 2 LMA is suitable for a child of 10-20kg
c. The formula for calculating ET tube length is: age/2 + 8
d. The dose of Suxamethonium is the same in children as for adults (i.e. 1.5mg/kg)
e. Laryngospasm is more common in children than adults

13. The following apply to epidural anaesthesia:
a. Opioids are 10 times more potent when administered via the epidural route (compared with intra-venous administration)
b. An INR > 2.0 is a contraindication to an epidural
c. It is safe to give a low molecular weight heparin within 12 hours of inserting or removing an epidural
d. Permanent nerve damage following an epidural can occur within 8 hours of initial symptoms
e. Skin infection at the site of epidural is a relative contraindication

14. The following are features of anaphylaxis:
a. Hypertension
b. Bronchospasm
c. Constipation
d. Coagulopathy
e. Vasculitic rash

15. The following are true of local-anaesthetic toxicity:
a. Local anaesthetic toxicity may present with dizziness
b. Local anaesthetic toxicity may present with numbness of the peripheries
c. Treatment is based on the A, B, C principle (i.e. successive attention to airway, breathing and circulation)
d. Seizures should not be treated pharmacologically
e. The maximum dose of prilocaine is 6mg/ kg

16. Percutaneous tracheostomy versus surgical tracheostomy:
a. Performing a percutaneous tracheostomy is a more simple procedure
b. A percutaneous tracheostomy requires a general anaesthetic
c. A surgical tracheostomy gives a better cosmetic result
d. There is a higher infection rate with percutaneous tracheostomy
e. There is a reduced risk of bleeding with a percutaneous tracheostomy

17. The following are true with regards to an older patient's physiology:
a. beta-receptors are less reactive in older people

b. There is an increase in forced expiratory volume in 1 second (FEV1) and vital capacity (VC)
c. There is a reduction in functional residual capacity (FRC)
d. The Glomerular filtration rate falls
e. Autonomic dysfunction is less common in the elderly

18. The following are true in Paediatric anaesthesia:
a. The formula for calculating endotracheal tube diameter is age/4 + 4
b. The Ayre's T-piece should be used in children up to a weight of 20 kg
c. A straight-bladed laryngoscope is recommended in children < 6 months old
d. Uncuffed tubes are advised in children until the age of 4
e. In infants the head should be in a neutral position for intubation

19. The following are true of levobupivicaine
a. It is more toxic than bupivicaine
b. Levobupivicaine is an amide
c. The pKa of levobupivicaine is 8.1
d. The recommended maximum dose of levobupivicaine is 5mg/kg
e. Levobupivicaine is more expensive than bupivicaine

20. The following apply to trauma situations:
a. A patient with a GCS < 9 should be intubated
b. In-line stabilisation of the neck may make intubation more difficult
c. Suxamethonium is the muscle-relaxant of choice when intubating trauma patients
d. A tension pneumothorax should initially be treated with needle decompression. The landmark is the 5th inter-costal space in the mid-clavicular line
e. The circulatory status should always be assessed first

Clinical Dilemma
Dr U. Schroeter, University Hospital Nottingham, UK

The Bleeding Tonsil
You have been called to see an 8 year old child who had a tonsillectomy six hours previously. The child is bleeding and needs to go back to theatre for haemostasis. When you arrive on the ward the child is agitated, tachycardic, pale and says he feels sick. The postoperative blood-loss is reported to be minimal by the nursing staff.

Questions
1) What are the specific problems in this case?
2) How would you manage the anaesthetic?

ANAESTHESIA FOR THE PREGNANT PATIENT WITH ACQUIRED VALVULAR HEART DISEASE

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Valvular heart disease in pregnancy poses additional risk to both mother and fetus.[1] Although there is an ever-decreasing prevalence of rheumatic heart disease in developed nations, it is still occasionally encountered. In the developing world it remains a significant problem.[2]

Management in pregnancy should be multi-disciplinary. Obstetric, cardiology and anaesthetic opinions should all be sought. The following need to be addressed: accurate diagnosis as to which valves are involved, assessment of the severity of the lesion, degree of impairment resulting from the lesion and evaluation of concomitant therapy. In addition, as well as optimising management during pregnancy and labour, it is important that care be carried on into the puerperium. The majority of reported deaths in cases of valvular heart disease in pregnancy occur in the post-partum period.[3] Intensive monitoring should be continued for at least 72 hours after delivery, preferably in a high care or intensive care environment.[4]

There are few evidence-based recommendations in the literature regarding the management of acquired valvular heart disease in pregnancy. Most recommendations are derived from case reports and observational studies. This article reviews current data and discusses important aspects of the anaesthetic management of valvular heart disease in pregnancy.

Cardiovascular physiology in pregnancy

Pregnancy stresses the cardiovascular system. Wide fluctuations in haemodynamic stress can be anticipated during labour and delivery. Patients with stenotic valvular lesions are particularly prone to complications at delivery, and the anaesthesiologist should be familiar with anticipated difficulties and their management. Patients may require invasive cardiac monitoring during labour, particularly where an operative delivery is anticipated.

Although patients may present with previously diagnosed valvular disease, cardiac compromise frequently only becomes apparent during pregnancy. This is largely due to the fact that normal pregnancy is associated with a 30 to 50 percent increase in blood volume and corresponding increases in cardiac output. Stroke volume normally increases by 25 to 30 percent, with the remaining increase in cardiac output being accounted for by

changes in heart rate.[5] Not surprisingly, where valvular heat disease limits these changes, cardiac compromise with pulmonary oedema or bi-ventricular failure may present early in pregnancy.

Early signs of cardiac compromise may become apparent in the first trimester and peak at 20 to 24 weeks of pregnancy when cardiac output reaches a maximum. From 24 weeks onward cardiac output is maintained at high levels. Cardiac output only begins to decline in the post-partum period.

During labour, the sympathetic response to pain, as well as uterine contractions, induce profound fluctuations in the patient's haemodynamic status. Between 300 and 500 ml of blood is injected into the general circulation with each contraction. Stroke volume rises by an estimated additional 50 percent. At the same time, systemic vascular resistance is increased, exacerbating the additional stress placed on the cardiovascular system. At delivery a predicted blood loss of between 400 and 800 ml does little to maintain stability in an already compromised circulatory system.

Many normal women manifest subtle signs of cardiac failure during uncomplicated pregnancy and delivery. Dyspnoea and fatigue are common, together with a reduction in exercise capacity. A large proportion of pregnant patients have peripheral oedema together with distension of the central veins and many have audible flow murmurs and a third heart sound indicative of volume overload.

Where underlying valvular disease is present it is hardly surprising that symptoms and signs of cardiac failure may occur during pregnancy or at the onset of labour.

Following delivery the cardiovascular status of the patient will normalise at 6 to 8 weeks post delivery.[6]

Identifying cardiac disease in pregnancy

The anaesthesiologist should be able to identify cardiac disease in pregnancy and labour if appropriate management decisions are to be made. The presence of the following physical signs should always be regarded as abnormal in pregnancy and alert attending physicians to the potential presence of underlying cardiac disease:

- A loud fourth heart sound
- Any diastolic murmur
- A grade 3/6 or more systolic murmur
- Fixed splitting of the second heart sound
- An opening snap

The presence of one or more of these signs indicates the need for echocardiographic evaluation of the heart.[7] Echocardiography has the ability not only to diagnose specific cardiac disease, but also to quantify the severity of cardiac lesions observed. This information is invaluable in both planning anaesthesia and anticipating complications.

Assessing risk in pregnant patients with cardiac disease

The New York Heart Association functional class has been used to identify patients at high risk of complication in pregnancy. A New York Heart Association functional class of III or IV has been estimated to carry a greater than 7 percent risk of mortality and a 30 percent risk of morbidity. Although women in these functional classes should be counselled against childbearing, it is not infrequent that they are encountered in the prenatal clinic (or even on the labour ward, or at the theatre door!).

New York Heart Association (NYHA) Classification
A functional classification of physical activity for acrdiac patients

- *Class I*: patients with no limitations of activities; they suffer no symptoms from ordinary activities
- *Class II*: patients with slight, mild limitation of activity; they are comfortable with rest or mild exertion
- *Class III*: patients with marked limitation of activity; they are comfortable only at rest
- *Class IV*: patients who should be at complete rest, confined to bed or chair; any physcial activity brings on discomfort and symptoms occur at rest

Following a study of 252 completed pregnancies in patients with cardiac disease, five risk factors were identified as being predictive of poor maternal and or neonatal outcome.[8] These were:

1. Prior cardiac events (heart failure, transient ischaemic attack or stroke)
2. Prior arrhythmias (symptomatic brady- or tachy-arrhythmia requiring therapy)
3. New York functional > class II or the presence of cyanosis.
4. Valvular or outflow tract obstruction (aortic valve area of less than 1.5 cm^2 or mitral valve area of less than 2 cm^2. Left ventricular outflow tract pressure gradient of more than 30mmHg)
5. Myocardial dysfunction (left ventricular ejection fraction of less than 40 percent, or a restrictive or hypertrophic cardiomyopathy)

A subsequently revised risk index identified four factors as being predictive of poor maternal and fetal outcome: [9]

1. Prior cardiac event
2. Poor NYHA functional class or cyanosis
3. Left heart obstruction
4. Systemic ventricular dysfunction

Valvular heart lesions and risk during pregnancy

During pregnancy, valvular heart lesions may carry risk for both mother and fetus. Complications ascribed to valvular heart disease include: increased incidence of maternal cardiac failure and mortality, increased risk of premature delivery, lower APGAR scores and lower birth weight. In addition there is a higher incidence of interventional and assisted deliveries.[10] The American Heart Association has classified cardiac lesions according to their associated risk. This is shown in the table

Classification of valvular heart lesions according to maternal, fetal and neonatal risk			
Low maternal and fetal risk	**High maternal and fetal risk**	**High maternal risk**	**High neonatal risk**
Asymptomatic aortic stenosis low mean outflow gradient (<50 mmHg) with normal left ventricular function	Severe aortic stenosis with or without symptoms	Reduced left ventricular systolic function (LVEF<40%)	Maternal age <20yr or >35 yr
Aortic regurgitation of NYHA class I or II with normal left ventricular systolic function	Aortic regurgitation with NYHA class III or IV symptoms	Previous heart failure	Use of anticoagulant therapy throughout pregnancy
Mitral regurgitation of NYHA class I or II with normal left ventricular systolic function	Mitral regurgitation with NYHA class III or IV symptoms	Previous stroke or transient ischaemic attack	Smoking during pregnancy
Mild to moderate mitral stenosis (valve area > 1.5 cm^2, gradient < 5mmHg) without severe pulmonary hypertension	Mitral stenosis with NYHA class II, III, or IV symptoms		Multiple gestations
Mitral valve prolapse with no mitral regurgitation or with mild to moderate mitral regurgitation and with normal left ventricular systolic function	Aortic valve disease, mitral valve disease, or both, resulting in severe pulmonary hypertension (pulmonary pressure > 75% of systemic pressures)		
Mild to moderate pulmonary valve stenosis	Aortic valve disease, mitral valve disease, or both, with left ventricular systolic dysfunction (EF < 40%) Maternal cyanosis Reduced functional class status (NYHA class III or IV)		

Table 1: Modified from Reimold and Rutherford[11]

below. [11] It is important for the anaesthesiologist to be aware of the attendant risk that a patient suffers as a result of valvular heart disease. Those patients carrying the highest risk warrant additional care, invasive haemodynamic monitoring and appropriate modification of anaesthetic technique.

In the absence of echocardiography, where more than one valvular lesion co-exists, the anaesthesiologist must attempt to identify the most clinically significant problem.

Mitral stenosis

Mitral stenosis is a commonly encountered lesion. It is associated with a maternal mortality of 10 percent. This increases to more than 50 percent in patients in NYHA functional class III and IV. Should concomitant atrial fibrillation be present, the risk of maternal mortality rises by between 5 and 10 percent.

The increasing physiologic demands of pregnancy are poorly tolerated; a progressively larger pressure gradient between left atrium and left ventricle develops. Pulmonary oedema, pulmonary hypertension and consequent right ventricular failure may all occur. At delivery tachycardia, pain, anxiety and anaemia dramatically increase the risk of acute pulmonary oedema and cardiovascular compromise.

In a small percentage of patients with mitral stenosis, pulmonary vascular resistance is greatly elevated, resulting in severe pulmonary hypertension, right heart failure, and low cardiac output. These patients are at high risk, and termination of pregnancy for the health and survival of the mother may require consideration.

Pain-mediated tachycardia increases flow across the mitral valve and may precipitate acute pulmonary oedema. The careful

provision of epidural anaesthesia by a skilled operator is therefore desirable for vaginal delivery (unless contraindicated for obstetric reasons). Epidural anaesthesia should be performed using small increments of local anaesthetic to achieve an adequate level (T8-T10). These patients are very sensitive to changes in preload and afterload; fluid and vasopressor therapy must be very carefully titrated against blood pressure. In severe cases (NYHA class III and IV), this is particularly important. In many cases, elective caesarean section under general anaesthesia may be the best option. In patients with advanced disease, invasive arterial monitoring is advisable. Small boluses of phenylephrine (50 mcg) are effective in avoiding precipitous hypotension. Small-dose, single shot spinal anaesthesia (e.g.1mL 0.25% bupivacaine with 10-20mcg fentanyl or 0.1-0.2mg morphine) may be used as an alternative to epidural anaesthesia in less experienced hands. This provides 2-4 hours of analgesia for labour. Combined spinal-epidural anaesthesia may have a role in the hands of experienced anaesthesiologists.

Pulmonary artery catheterisation has been advocated in patients with severe mitral stenosis, or mild-to-moderate stenosis with severe symptoms.[12] Fluid restriction, the use of diuretics and supplemental oxygen may all be of benefit.

The literature reports a case in which variation of the Trendelenburg position was used to maintain a capillary wedge pressure of 25mmHg during operative delivery. A successful outcome for both mother and foetus was reported.[13]

Atrial fibrillation must be treated promptly should it occur. Cardioversion, beta-blockers and digoxin have all been used to treat recent-onset (<24 hours) atrial fibrillation. Rate control is an important objective in attempting to normalise haemodynamics by allowing adequate diastolic filling of the ventricle.[14]

Caesarean delivery requires a block to a level of T4 (for light touch). Spinal anaesthesia is thus best avoided. Careful epidural anaesthesia in experienced hands may be considered in class 1 and 2 patients, but NYHA class 3 and 4 patients are often better managed under general anaesthesia. Specific pharmacotherapy must be employed to obtund the intubation response. Bolus oxytocin is contraindicated in view of the risk of precipitous systemic hypotension and pulmonary hypertension. A brief period of postoperative ventilation may be required in some cases.

In areas where the incidence of pre-eclampsia is high and valvular heart disease is prevalent, any patient developing pulmonary oedema should have mitral valve disease excluded as a contributing cause (as this is a particularly dangerous combination).

Mitral regurgitation

Mitral regurgitation is usually tolerated well during pregnancy. The marked decrease in systemic vascular resistance that occurs during pregnancy alleviates the abnormal physiologic stress imposed by this lesion. Rarely, reactive pulmonary hypertension and severe right heart failure may ensue.

There are no specific recommendations for the management of mitral regurgitation during labour and delivery. Prior to labour symptoms may be managed with diuretics and vasodilators. During labour, regional anaesthesia is usually well tolerated. However, in complicated NYHA class 3-4 cases, general anaesthesia may be required.

Aortic stenosis

In general the symptoms of aortic stenosis are masked by progressive left ventricular hypertrophy and are thus easily missed. Overall, patients who were asymptomatic prior to pregnancy usually tolerate pregnancy relatively uneventfully.

Echocardiographic determination of valve area is the best guide to severity of aortic stenosis. The hyperdynamic circulation of pregnancy frequently leads to overestimation of the degree of stenosis.

These patients tolerate tachycardia, hypovolaemia and systemic vasodilatation poorly, since coronary perfusion is critically dependent upon maintaining aortic diastolic pressure. General anaesthesia and caesarean section, with the aid of invasive haemodynamic monitoring, appears to be the safest means of successful delivery. Aggressive maintenance of systemic blood pressure with vasopressors (e.g. phenylephrine), is paramount to the avoidance of severe hypotension, acute left ventricular failure and cardiac arrest.

Spinal anaesthesia is generally contraindicated in these patients. There are reports of the successful management of vaginal delivery under carefully introduced and limited epidural analgesia, but this should be restricted to very experienced hands.

Aortic regurgitation

Aortic regurgitation reduces both cardiac output and coronary blood flow. The principles of management are: a reduction in afterload (to improve forward flow) and maintenance of a relatively high heart rate (to reduce the regurgitant fraction). In patients with aortic regurgitation there is reduced coronary flow in diastole; coronary flow has been documented to reverse in patients with severe aortic regurgitation. It is thus important to maintain systolic blood pressure within 15% of baseline levels in these patients. Many patients with aortic regurgitation improve symptomatically during pregnancy. During labour, epidural analgesia improves forward flow, and is therefore the anaesthetic of choice in patient's requiring an operative delivery.

Pulmonary stenosis

Pulmonary stenosis increases right ventricular work and can dramatically impair left ventricular output (due to reductions in forward flow). It is important to maintain preload and optimise ventricular contractility, whilst bearing in mind that excess fluid may precipitate acute right heart failure. Atrial fibrillation is also a potential complication of fluid overload.

The goals of haemodynamic management include maintenance of right ventricular preload, left ventricular afterload and right ventricular contractility. In general hypothermia, hypercarbia, acidosis, hypoxia and high ventilatory pressures should be avoided. Aorto-caval compression may result in profound hypotension as a result of acute reductions in right ventricular

preload. Most reports recommend vaginal delivery under epidural anaesthesia, as operative delivery is associated with increased maternal mortality.[8]

Spinal anaesthesia may be associated with an uncontrolled reduction in right ventricular preload and should therefore be avoided in severe cases.

Managing valvular heart disease in pregnancy

Although most pregnant patients with valvular heart disease may be managed medically during pregnancy, it is occasionally necessary to consider valve replacement. This may become a necessity in the patient with severe valvular disease (particularly stenosis), where termination of pregnancy is not considered to be an option. Severe symptomatic disease, threatening maternal or fetal well-being is an accepted indication for either balloon-valvuloplasty or valve replacement.[15]

When needed, valve replacement is best undertaken during the second trimester. Cardiopulmonary bypass and hypothermia carry substantial risk for the fetus. Fetal bradycardia and death are not uncommon.[15] Meticulous care should be given to the maintenance of blood pressure during bypass and fetal well-being should be monitored continuously with a cardiotocograph.

Bacterial endocarditis prophylaxis

Pregnancy carries no additional risk for bacterial endocarditis. The Committee on Rheumatic Fever, Endocarditis and Kawasaki Disease (American Heart Association), do not recommend routine antibiotic prophylaxis in patients with valvular heart disease undergoing uncomplicated vaginal delivery or caesarean section (unless infection is suspected). Antibiotic prophylaxis as practiced for the prevention of wound sepsis is more than adequate.

Antibiotics are optional for high-risk patients with prosthetic heart valves, a previous history of endocarditis, complex congenital heart disease or a surgically constructed systemic-pulmonary conduit.[16]

Pregnant patients with valvular heart disease should receive prophylactic antimicrobial therapy for invasive urinary tract or gastrointestinal procedures.[17] Intravenous ampicillin and gentamicin, or oral amoxycillin should be used in the non-penicillin allergic patient. Vancomycin and gentamicin are used in the patient with penicillin allergy.[16]

Anticoagulant therapy in patients with prosthetic valves

Although it is undeniably important to provide ongoing anticoagulation to the pregnant patient with a prosthetic valve, there is debate regarding the optimal agent. Unfortunately there are no randomised trials providing guidance in this area.[18] The use of warfarin and other coumadin derivatives carries a well-established risk of embryopathy, whilst the use of subcutaneous unfractionated heparin has been reported to be ineffective. Low molecular weight heparins have been considered as an alternative but data is limited to trials and reports of only 25 patients, with a treatment failure rate of 20%.[19] Data suggests that the low molecular weight heparins are neither safe, nor effective, in preventing thromboembolic complications in patients with prosthetic heart valves (whether pregnant or not).[20]

Traditional teaching is that patients should be anti-coagulated with heparin in the first trimester of pregnancy and then converted to warfarin for the remainder of the pregnancy. Warfarin should then be stopped just prior to delivery.

Fetal, but not maternal outcome has been reported to be better where bioprosthetic valves are used instead of mechanical prostheses (in both aortic and mitral positions).[21]

Conclusion

As a rule, regurgitant valvular lesions are far better tolerated in pregnancy than are stenotic lesions. Patients who are asymptomatic, or only have minimal symptoms before falling pregnant, tend to tolerate pregnancy well. Patients with severe symptomatic valvular heart disease should ideally be counselled against pregnancy. In the event of pregnancy, early consultation between obstetrician and anaesthesiologist allows for planning with regards to both the timing of delivery and optimal analgesia/ anaesthesia.

The main principles of management with regard to valvular heart disease in pregnancy are as follows:

- Early identification of the disease, and the assessment of the severity of the lesion(s).
- The appreciation of the severity of risk incurred by both mother and fetus.
- High-risk lesions, for either mother or fetus, should be managed in a high care environment where invasive monitoring is possible, both pre- and post delivery.
- Regional anaesthesia techniques in labour are an attractive option, and may be employed with good outcomes in many patients.
- Carefully titrated epidural anaesthesia for labour is associated with less sympathetic blockade than spinal or epidural anaesthesia for caesarean delivery. Thus, the effective use of regional anaesthesia for labour does not necessarily predict that this method will be safe for caesarean delivery in severe cases.
- Severe mitral or aortic stenosis, or any valvular heart condition associated with pulmonary oedema or heart failure, are contraindications to regional anaesthesia, (except in rare circumstances).

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DEPTH OF ANAESTHESIA

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Introduction

Assessment of the depth of anaesthesia is fundamental to anaesthetic practice. Prior to the use of muscle relaxants, maintaining the appropriate depth of anaesthesia was a balance between abolishing movement to pain whilst maintaining adequate respiration. With the absence of movement on incision it was safe to assume that the patient was not aware, however with the use of muscle relaxants it became necessary to be certain that the administered concentration of anaesthetic agent was adequate to prevent awareness. With the emergence of new anaesthetic techniques such as intravenous anaesthesia, the use of potent opiate analgesics, newer volatile agents and more complicated regional nerve blocks, a means of measuring depth of anaesthesia is important. What began as the continuous clinical monitoring of patients' physiological parameters evolved to include the measurement of real-time airway gas volatile agent concentration and more recently the analysis of neurophysiological parameters derived from the electroencephalogram (bispectral index and evoked potentials).

In patients who are aware during anaesthesia memory may be explicit or implicit. Explicit recall involves the memory of events and speech and may result in significant psychological sequelae. Implicit memory occurs where no recollection of events exists however patient's behaviour is modified by information given during anaesthesia. The incidence of awareness during anaesthesia with muscle relaxants is thought to be between 1:500 and 1:1000[1,2,] usually assessed by postoperative reporting and interview.

The prevention of awareness begins with scrupulous anaesthetic technique. This involves the checking of all equipment, ensuring the uninterrupted delivery of anaesthetic to patients via intact

circuits and intravenous access and the use of familiar, appropriate techniques by competent practitioners. This article discusses some of the common and developing methods used to aid the assessment of depth of anaesthesia in order to prevent intra-operative awareness.

Clinical parameters

It is essential to continuously monitor patients' respiration and autonomic parameters during anaesthesia. Measurement of heart rate and blood pressure whilst regularly assessing pupil size and the presence of sweating and lacrimation provide useful information regarding the adequacy of analgesia and depth of anaesthesia. However they must be taken into context with the surgical procedure and the anaesthetic technique, as cardiovascular parameters alone are poor predictors of the hypnotic state.[3] Tachycardia secondary to anti-cholinergic drugs like atropine make the heart rate uninterpretable and beta-adrenergic blocking drugs, opiates and regional anaesthetic techniques will obtund the sympathetic nervous system response to pain. Case reports have described cases of explicit awareness during anaesthesia, evident on electroencephalographic monitoring minutes before any significant cardiovascular changes occurred.[3]

Intravenous anaesthesia and pharmacokinetic modelling of agent concentration

The use of total intravenous anaesthesia (TIVA) is becoming more common. Unfortunately there is no equivalent of measuring end-tidal volatile agent concentration. Commercially available target-controlled infusion systems using propofol, estimate a plasma concentration using a pharmacokinetics model. However estimated blood concentrations do not correlate well with measured values due to inter-patient pharmacokinetic variability. Also the clinical effects of a particular drug concentration vary between patients.[2] A recent study has tested one of these propofol target -controlled systems in 22 patients undergoing laparoscopic cholecystectomy. When setting the target concentration at 2.5 mcg/ml measured plasma propofol concentrations ranged between 2.2 and 8.1mcg/ml. Propofol concentrations were under-predicted by a median of 60%. In addition Bispectral Index (BIS) monitoring was used to adjust propofol anaesthesia to maintain a target BIS value. The study found no correlation between measured serum propofol concentration and the corresponding BIS values 4. The accurate assessment of depth of anaesthesia during TIVA is difficult and care in preventing awareness, especially with the use of muscle relaxants, is important. Interestingly the quoted rates of awareness in studies using intravenous anaesthesia and muscle relaxants show a similar incidence to those using volatiles, (0.1-0.2%).

Isolated forearm technique

The isolated forearm technique was a method of detecting awareness during clinical practice and experimentally. A tourniquet is applied to the patient's upper arm, inflated above systolic blood pressure before the administration of muscle relaxants. Movement of the arm either spontaneously or to command indicated wakefulness, although not necessarily explicit awareness. It has been used previously as a means of detecting awareness during Caesarian section under general anaesthesia and during clinical trials assessing rates of awareness. Some would argue that response to command during surgery is a late sign when attempting to prevent awareness however not all patients responding have any recall. One study assessed response to command during deep sedation targeted using Bispectral Index monitoring of patients' EEGs. 56 patients in the study were repeatedly commanded to squeeze the observer's hand and 37 patients gave an unequivocal response at some point. Of these patients only 9 had any explicit recall of the events.[5] This demonstrates that post-operative recall and reporting by patients underestimates the incidence of wakefulness and 'near-awareness' during anaesthesia. Another study from 1986 compared an etomidate intravenous anaesthetic with nitrous oxide and fentanyl based anaesthesia. 44% of the nitrous oxide group showed signs of wakefulness whilst anaesthetised.[6] One limitation of this technique is the limited time available before patients are unable to move their arm due to tourniquet induced ischaemia.

Electroencephalographic methods

Interpreting the EEG during anaesthesia attempts to monitor the effects of anaesthetic agents in suppressing cerebral electrical activity. The EEG can be obtained with the standard 19-electrode method however this is time-consuming and impractical and requires expert interpretation. For some methods the use of bifrontal electrodes has been developed. Interpretation of the electrical signals with Fourier analysis describes the component waveform frequencies and amplitudes which can be displayed in a number of ways, for example as the compressed spectral array. As anaesthesia deepens the amplitude of the high frequency components falls with an increase at the lower frequencies. These changes are agent dependent, limiting the use of this technique as a depth of anaesthesia monitor. The Patient State Index is one EEG method of assessing hypnosis and was developed by comparing large numbers of EEGs during induction, maintenance and emergence. It assesses the patient EEG (mainly in the antero-posterior direction with less electrodes than conventional raw EEG acquisition) and calculates an index of hypnosis.[7] It is currently under clinical validation.

The Bispectral Index monitor (BIS) quantifies the phase relationships among the underlying sine wave components of the EEG and with the power and frequency information calculates a single numerical variable. 100 corresponds to the awake EEG and 0 to electrical silence. In applying it clinically a value of 65 to 85 is recommended for sedation and 40 to 65 as general anaesthesia. It has been found to correspond linearly with the hypnotic dose of intravenous or volatile agents used, correlating well with the hypnotic state and importantly is agent independent. However in comparison with MAC, BIS poorly predicts a movement or non-movement response, especially in the presence of opiates.[8]

BIS seems attractive as a monitor for intravenous as well as conventional volatile anaesthesia, but does it reduce awareness? Explicit awareness is uncommon so for a trial to have adequate power to show a significant reduction it would need to be very large.[2] Despite one recent trial[9] in nearly 5000 patients showing a reduction in explicit awareness compared to the incidence in a historical control group, there is limited clinical evidence to support this finding thus far.[2] Hypnotic titration, where the

intravenous or volatile agent is titrated to a target BIS value, has been studied. Its use has shown a reduction in anaesthetic usage with faster emergence times however no difference in the time for hospital discharge.[2,10] BIS does not actually correlate as well with measured propofol concentration as with an observer assessment of awareness and one concern is that in encouraging anaesthetists to run lower concentrations of anaesthetic agent to maintain a target BIS value it may encourage higher risk anaesthesia, potentially increasing the risk of awareness.

Some practical problems related to EEG based monitoring may occur. The EEG signal is prone to electrical interference in the theatre environment, especially with the use of diathermy and EMG activity from facial muscle and high electrode impedances may falsely elevate the calculated BIS values. The BIS cannot be used with ketamine due to its properties of EEG excitability and inaccuracies may arise with the use of nitrous oxide, which causes no change in BIS up to a concentration of 50%.

Auditory evoked responses (AER) represent the passage of electrical activity from the cochlea to the cortex in response to auditory stimuli administered via headphones, usually at 6-10Hz. These consist of an early brainstem response followed by early and late cortical responses. EEG analysis of the early cortical, (middle latency), activity reveals characteristic waveforms whose latency increases and amplitude decreases with the onset of anaesthesia, with subsequent reductions in amplitude as anaesthesia deepens.[11] AER monitoring correlates well with the transition from the awake to the asleep state, however predicts movement in response to painful stimuli poorly.[12] A middle latency AER monitor has been developed which calculates an index, (AAI) of 100 to 0, however it has not yet gained wide popularity as a depth of anaesthesia monitor. This may be partly due to problems relating to signal interference but also when comparing it to bispectral index the AAI monitor shows wide variation in awake values and overlap between the awake and asleep state. It has been reported to have successfully detected awareness intraoperatively[3] however and may emerge as a useful tool in the future.

Bispectral Index Values	
100	awake
65 - 85	sedation
45 - 65	general anaesthesia
<40	burst suppression
0	no electrical activity

MAC

The measurement of end-tidal volatile anaesthetic agent concentration is a standard component of modern anaesthetic monitoring. It led to the concept of MAC and provides the best available method to monitor continuous brain concentration of volatile anaesthetics provided adequate time is allowed for equilibration between alveolus, blood and effect site. Inhalational agents including nitrous oxide are considered additive in their actions and contribution to MAC but it must not be forgotten that their pharmacokinetics are different depending on relative solubilities.

MAC is the minimum alveolar concentration of anaesthetic agent at 1 atmosphere pressure producing immobility in 50% of subjects exposed to a standard painful stimulus and has been studied extensively in animals and humans. Two common designs are used, quantal and bracketing.[13] Quantal study designs, used in human trials, involve the exposure of a known concentration of agent for a defined time whereupon a standard noxious stimulus is applied. Movement or non-movement is recorded. The probability of non-movement as a function of anaesthetic dose can be calculated for the population with MAC being the 50% effective dose (ED50). MAC is normally distributed. Bracketing designs calculate MAC for individual animals by incremental changes in dose until non-movement to pain occurs. The two methods correlate closely. Due to the accuracy of modern gas analysers and the move/non-move endpoint MAC studies are precise, showing a low biological variability in MAC with standard deviations quoted at 10-20%.[14]

The movement response to a skin incision under volatile anaesthesia is mediated partly at a spinal level by inhibiting spinal reflexes 8. This characteristic of inhalational anaesthetics is not shared by the intravenous anaesthetic propofol. The observation that patients lose consciousness at anaesthetic doses less than 1MAC led to the concept of MACawake This is more difficult to determine accurately, varying between agents, but is around 0.5MAC or less for the less soluble agents. MACawake being less than 1 MAC is reassuring in terms of awareness during anaesthesia.

MAC is decreased by a number of factors. These include decreasing body temperature, hypoxia and acidosis, sedative drugs including alpha2 agonists, systemic and epidural opiates and also with age. This reduction with age occurs at the same rate for all volatile agents and was quantified and published by Mapleson who calculated a 6% decline per decade after the first year of life. The concept of age-related MAC has been developed with the publication of age-related iso-MAC charts[15] and more recently an age-related MAC nomogram.[16] These charts allow the estimation of appropriate end-tidal isoflurane, sevoflurane and desflurane concentration to provide particular MAC values over a range of ages and in the presence of 0%, 50% and 67%

Variants of MAC	
MAC	The minimum alveolar concentration of anaesthetic at 1 atmopshere pressure producing immobility in 50% of subjects
MAC_{awake}	The minimum alveolar concentration of anaesthetic producing unconsciousness in 50% of subjects
MAC_{bar}	The minimum alveolar concentration of anaesthetic producing blocking the sympathetic nervous system response to a painful stimulus in 50% of subjects

EEG-based Methods of Monitoring Depth of Anaesthesia	
Raw EEG Multiple leads	19 Lead Bulky Difficult Interpretation Inter-anaesthetic agent differences
Compressed Spectral Array Frontal electrodes	Graphical display of component EEG frequency amplitudes Fourier Analysis Reduced higher frequency, increased low frequency amplitudes with anaesthesia Easier to interpret than raw EEG Agent dependent changes
Patient State Index	Index of state of hypnosis/awareness From retrospective analysis of multiple 19 lead EEGs throughout anaesthesia Compares EEG to population electrophysiological distribution of EEG changes Agent independent Predicts anaesthetic state with PSI value
Bispectral Index Frontal electrodes	Combines spectral array and phase relationships of component sine waves Provides single numerical value 0-100 (complex statistical analysis) Correlates linearly with dose of hypnotic agent Agent independent In hypnotic titration BIS reduces anaesthetic dosage and recovery time Does not affect time to discharge Inaccurate with ketamine Not yet established whether BIS reduces incidence of awareness
Auditory evoked potentials Vertex, mastoid, forehead electrodes	EEG activity in response to auditory clicks via headphones Characteristic early cortical responses that change with anaesthesia Reduced latency and amplitude of waveform with anaesthesia Correlates with awake to asleep transition Clinical monitor developed but inter-patient variability in values
General problems	Electrical interference (mains, diathermy, facial muscle EMG) Electrode impedance may cause inaccuracies Excitatory anaesthetic agents cause inaccuracies (ketamine) Patients with abnormal EEG's (Fitting, head injury, etc)

nitrous oxide. They show a wide variation in MAC at extremes of age exaggerated further by the age variation in MAC for nitrous oxide. These are clinically very useful in preventing not only awareness but also the administration of too much anaesthetic to the elderly.

MACbar is the minimum alveolar concentration of anaesthetic agent inhibiting the sympathetic nervous system response to a standard noxious stimulus in 50% of subjects. It shows some variation between agents however is universally reduced by the administration of opiates. Beyond a certain dose no further reduction occurs. Opiates alone do not produce anaesthesia regardless of dose despite producing a small reduction in MACawake therefore it is still essential to administer enough anaesthetic agent to prevent awareness even when high doses or potent opiates like remifentanil are used, for example during cardiac surgery. This is also the case when regional blocks are used to abolish surgical stimulation.

Despite the advances in some EEG-based anaesthesia monitoring, the low inter-patient variability in MAC measurements still suggest that end-tidal agent monitoring provides anaesthetists with the best guide to assessing anaesthetic depth. It is not so easy to simply compare confidence intervals of MAC measurements and EEG derived monitoring for a number of reasons. During the development of BIS monitoring it was tested in the context of volatile anaesthesia and move /non-move endpoints. However with the increasing use of intravenous anaesthesia, the effect of opiates on the move endpoint, its inferior ability to predict movement compared to volatile agent monitoring and the difference in the hypnotic and analgesic components of anaesthesia, the software was reformulated.[8] A recent study assessing BIS values in children receiving various doses of isoflurane showed standard deviations of around 30% around

Factors increasing MAC	**Factors decreasing MAC**
Age: children	Age: elderly
Hyperthermia	Hypothermia
Hyperthyroidism	Hypoxia
Alcoholism	CNS depressants
	N_2O and other volatile agents

the mean BIS values.[17] It has already been mentioned that the inter-patient variability in the pharmacokinetics and pharmacodynamics of propofol during its administration by target-controlled infusion systems is large making its assessment of anaesthetic depth during total intravenous anaesthesia less reliable.

1.0 MAC: **End tidal isoflurane in:**			
Age	**100% O_2**	**50% N_2O**	**67% N_2O**
1	1.5	0.95	0.75
10	1.4	0.85	0.65
20	1.3	0.75	0.55
30	1.25	0.65	0.5
40	1.15	0.6	0.4
50	1.1	0.55	0.35
60	1.05	0.45	0.25
70	1	0.4	0.2
80	0.9	0.35	0.15
90	0.85	0.3	0.1

Lower oesphageal contractility

Spontaneous and provoked lower oesophageal contractions both reduce in latency and amplitude during general anaesthesia. These are measured using a balloon in the oesophagus however published evidence of its use as a depth of anaesthesia monitor is limited.

Conclusion

It seems that the measurement of end-tidal volatile agent concentration currently provides the most objective estimate of brain anaesthetic concentration available and has stood the test of time. Quantifying the effect of anaesthetics on brain activity is an attractive proposition for monitoring both volatile and intravenous anaesthesia and in time EEG-based monitoring may prove to be a sensitive indicator of depth of anaesthesia to use in conjunction with the conventional means at our disposal to prevent intra-operative awareness.

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FROM THE JOURNALS

Peter J. Shirley - Anaesthesia,
Damaris Kohler -Anaesthesia and Intensive Care,
Aneeta Sinha - Canadian Journal of Anesthesia,
Michael Girgis - Anesthesiology

Viral gastroenteritis - a danger to the patient, a danger to the staff.

Appelboam R, Hammond E Anaesthesia 2004;59:293-5

A previously well 74 year-old lady was admitted in shock, with an acute abdomen. This was initially thought to be a ruptured abdominal aortic aneurysm. After resuscitation, a laparotomy was performed. No intra-abdominal pathology was revealed. Further review of X-rays and the clinical presentation lead to the discovery of an oesophageal rupture which was thought to be due to vomiting (Boerhaave's syndrome). She subsequently underwent a thoracotomy and sub-total oesophagectomy. Intra-operative time was eight hours (involving at least one change of theatre, anaesthetic and surgical staff). Over the following two days, 18 personnel, all involved in the patients care, became unwell with a rapid-onset acute illness. This was characterised by severe epigastric pain, nausea, vomiting and diarrhoea. In total 90 man-days were lost due to absences of ill staff members.

The probable cause of the patient's illness was thought to be a small round-structured virus (SRSV). Subsequent enquiries by the hospital's Public Health Department revealed a direct correlation between exposure to the patient and development of symptoms.

This case highlights the importance of using universal barrier precautions (gloves, fluid resistant mask, face shield and gown) when dealing with infective patients. Although all staff wore gloves, the other precautions were not strictly adhered to. (The routine wearing of face-masks in the operating theatre by anaesthetists in the UK is thought to be about 32.5%). Moreover, the high turnover of staff during this case probably contributed to the numbers of infected personnel. This case-report serves to underline the importance of basic hygiene procedures in the technology-rich environment of the operating theatre.

Forehead SpO_2 monitoring compared to finger SpO_2 recording in emergency. transport.

Nuhr M, Hoerouf K, Joldzo A et al Anaesthesia 2004;59:390-3

This is a short paper looking at a new oxygen saturation monitor, and comparing it with a standard finger probe for use during emergency transport. The latest pulse oximetry technology has been adapted to cope with motion and cold ambient temperatures. The new pulse oximeter incorporates an adhesive forehead sensor. (Nellcor / Tyco Healthcare, Vienna, Austria). The authors tested the hypothesis that this new technology is superior to conventional finger pulse oximetry in an emergency care and transport setting.

53 patients, all of whom were mildly hypothermic (less than 36∞C; mean 35.6°C) and had suffered minor trauma (Injury Severity Score ISS <10) were enrolled. All patient's had both finger and forehead oximetry performed. The forehead technique malfunctioned (i.e. alarm incorrectly going off) on significantly fewer occasions than the standard oximeter. The duration of these malfunctions was also shorter than those seen with traditional finger pulse oximetry.

The authors conclude that the new technology provides better monitoring quality in emergency care, and as such provides an important contribution to patient safety. They also point out that the distractions to attendants from frequent 'malfunction' alerts are reduced. This enables care to be enhanced in other areas.

Whilst not directly applicable to less resource-rich medical systems, this study shows what technological advances will be available in time.

Muscle weakness after muscle relaxants: an audit of clinical practice.

Alkhazrajy W, Khorasanee AD, Russell WJ Anaesthesia and Intensive Care 2004;32:256-9.

The extent of residual muscle weakness after general anaesthesia was measured by measuring handgrip strength with a dynamometer preoperatively, one hour postoperatively and 24 hr after surgery. Three groups of patients were compared. The first group did not receive a relaxant, the second had vecuronium and the third rocuronium in dosages that were considered adequate for the surgical procedure by an independent, experienced anaesthesiologist. All patients who received a relaxant were reversed with neostigmine.

The study showed that there was no effect on handgrip strength one hour postoperatively by the patients' age, length of operation or preoperative physical condition of the patient. However,

females showed significantly reduced handgrip strength at one hour, although they had received similar absolute doses compared to men. This difference was highly significant (p=0.0002). At 24 hours postoperatively full recovery had taken place.

The authors conclude that women are significantly more sensitive to relaxants than men (requiring 22% less drug on a per kilogram basis, according to another study), and that this leads to a higher risk of the effects of muscular weakness in the immediate postoperative period.

Oral ketamine or midazolam or low dose combination premedication in children.

Darlong V, Shende D, Subramanyam MS, Sunders R, Naik A Anaesthesia and Intensive Care 2004;32:246-9.

Ketamine 6mg/kg orally or midazolam 0.5mg/kg orally were compared to a premedication of a combination of both (ketamine 3mg/kg plus midazolam 0.25mg/kg orally) in healthy children undergoing ophthalmic surgery. The drugs had been prepared in solution with glucose 50% to give a volume of 0.3ml/kg. The time for achieving satisfactory sedation, good conditions for separation from the parent, tolerance to the face mask, behaviour during emergence and time to reach a sufficient Aldrete recovery score were compared.

At 20 minutes after administration, more than 50% of the children receiving the combination were sufficiently sedated (p=0.008). At 30 minutes no significant differences were noted. Parental separation was easy after 19 minutes in the combined midazolam/ketamine group, but only after 28 and 29 minutes following midazolam or ketamine respectively (p=0.001).

Recovery time was 22 minutes in the combination group and 36 and 38 minutes with midazolam and ketamine alone respectively. PONV occurred in all three groups with a similar rate. Excessive salivation occurred in 50% of the ketamine only group.

The study showed that a combination of low doses of midazolam plus ketamine had a faster onset, better efficiency and more rapid recovery than the administration of the single drugs in a higher dose.

Practical Note: to prepare a solution as described, mix 9ml ketamine 5% (50mg/ml) with 7.5ml midazolam (5mg/ml) and add 28.5ml Glucose 50% to make 45ml of the solution. This will last for "150kg of children", receiving 0.3ml/kg

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Full scale computer simulators in anaesthesia training and evaluation.

Wong AK Canadian Journal of Anesthesia 2003;4:392-7

Medical education is changing. The shift to a competency-based curriculum and the demand for public accountability places increased emphasis on more objective, performance-orientated tests of clinical competence. This article reviews the current role of full-scale computer simulators in anaesthetic training and evaluation.

The use of simulators in anaesthesia has increased significantly over the last decade. They allow for repeated practice of managing problems that occur infrequently but require expert intervention for a successful outcome, for practising leadership and communication skills in a team-orientated approach and for experiential learning in a realistic, safe, controlled environment that does not expose patients to harm. Direct feedback, videotape recording, the option of stopping and restarting, predictability, reproducibility and standardisation are all additional advantages.

However, despite the increasing use of full-scale simulators in anaesthesia, definitive studies evaluating their cost-effectiveness, efficacy compared to traditional training methods or their impact on patient outcome are still pending. Some preliminary evidence of reliability and validity in using the simulator to evaluate clinical competence has been found, but not enough to justify its use in formal summative evaluation of competence in anaesthesia.

There is no doubt that a variety of teaching modalities and assessment techniques are required in medical training and evaluation of competency. Computer simulators certainly have exciting potential as an adjunct and not a replacement for experiential learning and evaluation. However, a better understanding of their strengths and limitations is required. This interesting article leaves one pondering the future of simulator technology in anaesthesia education.

Labor analgesia and Cesarean delivery: an individual patient meta-analysis of nulliparous women.

Sharma SK, McIntire DD, Wiley J, Leveno KJ. Anesthesiology 2004;100:142-8

In this study the authors perfon individual patient meta-analysis of 2703 nulliparous women who were randomised using computer designed sequences to either epidural analgesia or intravenous meperdine (pethidine) for pain relief during labour.

Patients were obtained from five trials conducted between 1993 and 2000 at Parkland Hospital, and those eligible included uncomplicated pregnancies and women with pregnancy-induced hypertension, at 36 or more weeks gestation. Obstetric management was according to a written protocol, which involved intravenous fluid administration; fetal heart rate surveillance for 30 minutes after commencement of analgesia; continuous heart rate monitoring in those with meconium stained amniotic fluid, auscultated fetal heart rate decelerations or inadequate progress of labour; and 2 hourly pelvic examinations. Cervical change of less than 1cm/hr with hypotonic uterine contractions resulted in augmentation of labour with oxytocin.

Indications for use of forceps were limited to inadequate voluntary pushing or fetal heart rate abnormalities. Epidural analgesia was initiated with either epidural bupivacaine or intrathecal sufentanil, and maintained with various concentrations of bupivacaine and fentanyl. Analgesia was maintained throughout the first stage of labour. Inadequate progress in the second stage after 1 hour resulted in halving or discontinuing the infusion to restore expulsive efforts. Additional boluses of bupivacaine and/or fentanyl were given for inadequate analgesia. All women randomised to meperidine (pethidine) were given an initial bolus of 50mg followed by either boluses or patient controlled analgesia for maintenance.

All tests of significance were performed using two-tailed tests and analysed according to intention-to-treat analysis. Having data available for the individual patients allowed the incorporation of general statistical methods adjusting for the individual studies. 1339 were allocated to epidural analgesia and 1364 to intravenous meperidine (pethidine). 19% were diagnosed with pregnancy-induced hypertension. 18% in the epidural group and 13% in the intravenous group did not receive allocated analgesia. The reasons were either rapid delivery, analgesia refused, randomisation error or received meperidine (pethidine) or epidural respectively. 12% in the intravenous group crossed over to epidural analgesia because of ineffective analgesia. There were no significant differences in maternal demographics, cervical dilatation at time of analgesia or number with pregnancy-induced hypertension between the two groups.

Epidural analgesia was significantly associated with prolongation of the first ($p<0.011$) and second ($p<0.001$) stages of labour, the need for labour augmentation ($p<0.001$), maternal fever ($p<0.001$), and increased rate of forceps delivery (adjusted OR 1.86; 95% CI 1.43-2.40 $p<0.001$). There was no significant difference in the caesarean delivery rate between epidural analgesia (10.5%) and intravenous meperidine (pethidine, 10.3%). The caesarean delivery rate was similar among the different methods of epidural analgesia used. One and five minute Apgar scores less than 7 were significantly increased in the intravenous meperidine (pethidine) group. Analysis of the protocol compliant groups showed similar results. The caesarean delivery rate was significantly increased in those who crossed from meperidine to epidural analgesia compared to those who did not ($p<0.001$). 95% of women who received epidural analgesia rated their satisfaction as excellent compared to 69% who received intravenous meperidine (pethidine).

SELF ASSESSMENT - Answers to MCQ

Dr B Newstead
Dr U Schroeter

1.

a. **F** - it takes about 2 hours for clear fluids to empty from the stomach

b. **T**

c. **F** - milk thickens when mixed with gastric juice and should be regarded as a solid

d. **T**

e. **F** - aspiration of as little as 30-40 mls can result in lung damage

2.

a. **T** - (see below)

b. **F** - current recommendations are that supplementary steroids are only needed if the patient is on a dose of 10mg prednisolone (or more)/ day

c. **T**

d. **F** - 10mg prednisolone is equivalent to 1.5 mg dexamethasone

e. **F** - a dose of 25mg hydrocortisone on induction is considered sufficient

Prednisolone 10mg is equivalent to:

- Dexamethasone 1.5mg
- Hydrocortisone 40mg
- Methylprednisolone 8mg
- Betamethasone 1.5mg
- Cortisone acetate 50mg

3.

a. **F** - whilst severe aortic stenosis can present with chest pain, breathlessness and syncope, it can also be entirely asymptomatic (and may present for the first time with sudden death).

b. **T**

Degree of severity of aortic stenosis	**Gradient across aortic valve**
Mild	< 40mmHg
Moderate	40-80 mmHg
Severe	>80 mmHg

c. **F** - a spinal anaesthetic leads to a sympathetic block leading to a fall in blood pressure. This is clearly something to be avoided in patients with a relatively fixed cardiac output.

d. **F** - the loudness of the murmur bears no relation to the severity of the aortic stenosis. In fact, in very severe stenosis the murmur is often very quiet (due to falling cardiac output).

e. **F** - Metaraminol (or similar) would be first choice as it does not cause a tachycardia (and thus avoids stressing the heart any further).

4.

a. **F** - TURP is often done under a spinal anaesthetic. This avoids the risk of a general anaesthetic in an often frail population. It also enables TUR syndrome to be picked up earlier (through regular conversation with the patient).

b. **T**

c. **F** - Hyponatraemia should not be corrected at a rate faster than 1mmol/L/hour

d. **T**

e. **F** - most patients are elderly and often have significant co-morbidity. A minimum of FBC/ U&E/ G&S and an ECG is recommended.

5.

a. **F** - Suxamethonium is the only depolarising muscle relaxant in clinical use

b. **T**

c. **F** - Suxamethonium causes an increase in potassium of 0.5mmol/Litre. This is of little significance in most individuals. However caution must be exercised in patients with a pre-existing hyperkalaemia e.g. burns patients, patients with renal failure.

d. **F** - Suxamethonium may cause bradycardia in children. This may be prevented with atropine or glycopyrolate.

e. **F** - 4-5% of the population have this atypical gene

6.

a. **F** - Hypocalcaemia is a risk factor as it predisposes to neuromuscular irritability

b. **T**

c. **T** - Gaseous induction leads to a lighter plane of anaesthesia than IV induction, and therefore means laryngospasm is more likely

d. **T** - There is an increased chance of a soiled airway following a tonsillectomy and laryngospasm is thus more likely.

e. **F** - This is not a particularly stimulating operation. If it was associated with an anal stretch then this would predispose to laryngospasm. (Intense surgical stimulus = Increased risk of laryngospasm)

7.

a. **T**

b. **F** - Full thickness burns destroy the nerves and are therefore painless

c. **F** - There is no evidence that routine administration of antibiotics influences outcome

d. **F** - Parkland formula = 2-4mls fluid per % burn per kg of weight

e. **T** - Intubation is likely to become more and more difficult as airway swelling occurs

8.

a. **T** - Raynaud's disease leads to vasospasm of the blood vessels in the fingers. A tourniquet is going to compound the problem and increase the risk of tissue necrosis.

b. **T** - the tourniquet pressure would be too high

c. **F** - A Bier's block is often safer than a general anaesthetic in the elderly

d. **T** - A Bier's block may provoke further tissue damage

e. **F** - A Bier's block is likely to be safer than a GA

9.

a. **T** - We have a much higher threshold for transfusing blood products these days because of the risks of viral transmission.

b. **F** - the dose is 10-15 mls/kg (This will lead to an increase in coagulation levels of about 15%)

c. **T**

d. **F** - A cross-match can be done within 20 minutes

e. **T**

10.

a. **F** - T he spinal cord ends at L1-L2

b. **T** - this is to ensure that the injection is given at a level lower than the spinal cord

c. **F** - Most clinicians would consider this to be a relative contraindication (due to possible technical difficulty).

d. **F** - Heavy bupivicaine will give a higher block as a result of increased spread of the hyperbaric solution in the intrathecal space.

e. **T**

11.

a. **T** - In the head- down position there is reduced lung compliance and functional residual capacity

b. **T** - In the prone position, access to the airway is extremely limited and the patient should therefore be intubated (preferably with an armoured ET tube).

c. **F** - In the head-up position there is reduced venous return and therefore decreased cardiac output and BP.

d. **F** - The head should be turned towards the abducted arm to prevent stretch of the brachial plexus

e. **T**

12.

a. **F** - the correct formula is: (age + 4) multiplied by 2

b. **T**

Weight of child	**Size of LMA**
5-10 kg	1.5
10-20 kg	2.0
20-30 kg	2.5
30-50 kg	3.0

c. **F** - the correct formula is: age/2 + 12

d. **F** - the recommended dose in children is 2mg/kg due to their increased volume of distribution

e. **T**

13.

a. **T**

b. **T** - an INR > 1.5 is a contraindication to administering an epidural

c. **F** - A minimum of 12 hours should be left between giving a low molecular weight heparin and inserting/removing an epidural. This will minimise the chance of bleeding

d. **T** - back pain/ nerve root pain and neurological symptoms should therefore always be taken very seriously

e. **F** - Most clinicians would consider this to be an **ABSOLUTE** contraindication

14.

a. **F** - patient's are usually hypotensive as a result of peripheral vasodilatation

b. **T**

c. **F** - the patient may have abdominal pain and diarrhoea (not constipation)

d. **T**

e. **F** - the patient may be flushed or have an urticarial rash or erythema (not vasculitis)

15.

a. **T** - early signs of local anaesthetic toxicity include dizziness, light-headedness and drowsiness

b. **F** - an early sign of local anaesthetic toxicity is circum-oral numbness (as a result of the numerous nerve endings in this region)

c. **T**

d. **F** - Seizures should be treated with conventional anti-convulsants e.g. diazepam, lorazepam, thiopentone

e. **T**

16.

a. **T** - Anaesthetists can be trained to perform percutaneous tracheostomy relatively simply

b. **F** - A percutaneous tracheostomy can be performed under local anaesthetic and sedation

c. **F**

d. **F** - A 3% infection rate is quoted for percutaneous tracheostomy (versus 30% for a surgical procedure)

e. **T** - A percutaneous tracheostomy results in a stoma being formed between the tracheal rings. This does not normally lead to blood vessel damage.

17.

a. **T** - this leads to a blunted response to cardiovascular stress

b. **F** - there is a reduction in both FEV1 and VC

c. **F** - FRC remains about the same regardless of age

d. **T**

e. **F** - Autonomic dysfunction is more common in the elderly. This means that a labile BP and arrhythmias are more likely

18.

a. **T**

b. **T** - this is a low-resistance circuit. The expiratory limb exceeds the child's tidal volume, and thus prevents entrainment of room air

c. **T**

d. **F** - unruffled tubes are advised until the child reaches puberty. This is because the tracheal tube tends to lie at the level of the cricoid ring. This is particularly susceptible to oedema in children and an inflatable cuff is therefore avoided.

e. **T**

19.

a. **F** - it is less toxic. The D-isomer of bupivicaine has a higher potential for cardiotoxicity. Thus if the L-isomer is used in isolation it will be safer

b. **T**

c. **T**

d. **F** - The maximum recommended dose is 2mg/kg

e. **T**

20.

a. **F** - A GCS equal or less than 8 is an indication for intubation

b. **T** - 20% of patients will have a grade 3 view of the larynx

c. **T** - A full stomach must always be assumed and therefore a rapid-sequence induction performed

d. **F** - the landmark is the 2nd inter-costal space in the mid-clavicular line

e. **F** - Trauma patients should always be resuscitated using the A, B, C approach (airway, breathing, circulation) i.e. problems with the airway and breathing should be attended to before moving on to look at the circulation

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Answer to Clinical Dilemma

- **Hypovolaemia**. The blood-loss is difficult to assess because most of the blood is swallowed. Children are also able to compensate well following blood loss. Signs of significant hypovolaemia include agitation, depressed conscious level, tachycardia, prolonged capillary refill time (> 2 seconds), pale mucus membranes, cool peripheries and weak peripheral or central pulses. Hypotension is a late and often sudden sign of decompensation. If hypotension it is not rapidly reversed, death may ensue very quickly.
- **Residual effect of the last anaesthetic**. Depressed conscious level from volatile agents and/or opioid analgesics. Minor degree of subglottic oedema from the endotracheal tube.
- **Potentially difficult airway**. Postoperative oedema and bleeding can make it difficult to visualise the larynx.
- **Full stomach**. There is a significant amount of blood in the stomach.

Anaesthetic Management

- **Preoperatively**. Resuscitate the child (crystalloid, colloid and/or blood, depending on haemoglobin level and availability). Cross match blood if necessary. Prepare the usual equipment and monitoring. Ensure that large bore suction is readily available. Check the previous anaesthetic chart for details of the intubation. Prepare the same size ETT and have two smaller sizes of ETT available. (For an 8 year old a size 6, 5.5 and 5). A senior anaesthetist and ENT surgeon should be available during induction.
- **Induction**. There are two options. The classical teaching is an inhalational induction with halothane or sevoflurane in the left lateral position. Potential problems are hypotension in the hypovolaemic patient and laryngospasm. Many anaesthetists are not familiar with this technique and this in itself may prove a disadvantage. Most anaesthetists use a conventional, intravenous rapid sequence induction. The principles are pre-oxygenation, use of short acting induction agents (i.e. thiopentone, etomidate, ketamine), muscle relaxation with fast onset and rapid recovery (suxamethonium) and cricoid pressure. Choose the technique YOU are most familiar with. A failed intubation plan must be prepared.
- During surgery empty the stomach with a large bore oro-gastric tube. Remove the tube. The patient should be extubated awake in the lateral position.
- Postoperatively there is a risk of further re-bleeding and the patient therefore needs to be closely monitored.

MANAGEMENT OF ORGANOPHOSPHORUS POISONING

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Organophosphorus compounds are chemical agents in wide-spread use throughout the world, mainly in agriculture. They are also used as nerve agents in chemical warfare (e.g. Sarin gas), and as therapeutic agents, such as ecothiopate used in the treatment of glaucoma. They comprise the ester, amide or thiol derivatives of phosphoric acid and are most commonly used as pesticides in commercial agriculture, field sprays and as household chemicals. Organophosphates are of significant importance due to their practical usefulness and chemical instability. This instability means a lack of persistence in their surroundings.

There are no rules and regulations governing the purchase of these products, and they are therefore readily available "over the counter", despite them being a major cause of morbidity and mortality. Exposure to organophosphates in an attempt to commit suicide is a key problem, particularly in the developing countries, and is a more common cause of poisoning than the chronic exposure experienced by farmers or sprayers in contact with pesticides. Estimates from the WHO indicate that each year, 1 million accidental poisonings and 2 million suicide attempts involving pesticides occur worldwide. Intoxication occurs following absorption through the skin, ingestion via the GI tract or inhalation through the respiratory tract. Early diagnosis and prompt treatment is required to save the patient's life.

Classification:

There are more than a hundred organophosphorus compounds in common use. These are classified according to their toxicity and clinical 1 use:

1. Highly toxic organophosphates: (e.g. tetra-ethyl pyrophosphates, parathion). These are mainly used as agricultural insecticides.
2. Intermediately toxic organophosphates: (e.g. coumaphos, clorpyrifos, trichlorfon). These are used as animal insecticides.
3. Low toxicity: (e.g. diazinon, malathion, dichlorvos). These are used for household application and as field sprays.

Mechanism of Action of Organophosphorus Compounds

Acetylcholine (ACh) is the neurotransmitter released at all postganglionic parasympathetic nerve endings and at the synapses of both sympathetic and parasympathetic ganglia. It is also released at the skeletal muscle myoneural junction, and serves as a neurotransmitter in the central nervous system.[2] ACh is hydrolyzed by acetylcholinesterase into two fragments: acetic acid and choline.

Acetylcholinesterase is present in two forms: True acetylcholinesterase which is found primarily in the tissues and erythrocytes, and pseudocholinesterase which is found in the serum and liver.

Organophosphorus compounds are acid-transferring inhibitors of cholinesterase. They cause cholinesterase to become firmly (and sometimes irreversibly) phosphorylated. This means that the action of cholinesterase will be inhibited. Cleavage of the carbon-enzyme bond from ACh is complete in a few microseconds. However, the breaking of the phosphorus-enzyme bond requires a period varying from 60 minutes to several weeks, depending on the organophosphorus compound involved.

Reactivation of the inhibited enzyme may occur spontaneously. The rate of reactivation will depend on the species, the tissue, and the chemical group attached to the enzyme. Reactivation may be enhanced by hydrolysis of the acid-radical-enzyme through the use of oximes (i.e. reactivating agents). Response to reactivating agent's declines with time; this process being caused by "ageing" of the inhibited enzyme. Ageing is probably the result of the loss of one alkyl or alkoxy group, leaving a much more stable acetylcholinesterase.[3] The aged phosphorylated enzyme cannot be reactivated by oximes.[4]

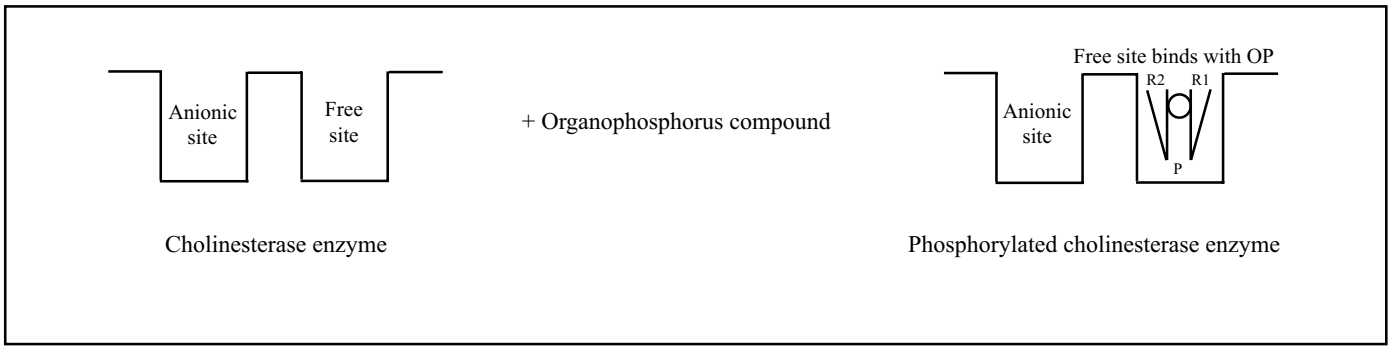
Accumulation of acetylcholine causes overstimulation of both muscarinic and nicotinic receptors, and subsequently disrupts the transmission of nerve impulses in both the peripheral and central nervous system.

Pharmacokinetics

Most organophosphates are highly lipid soluble compounds and are well absorbed from intact skin, oral mucous membranes, conjunctiva and the gastrointestinal and respiratory tracts. They are rapidly redistributed to all body tissues. The highest concentrations are found in the liver and kidneys. This high lipid solubility means that they easily cross the blood/brain barrier and therefore produce potent effects on the CNS. Metabolism occurs principally by oxidation in the liver with conjugation and esterase hydrolysis producing a half-life of minutes - hours. The oxidative metabolites of malathion and parathion (malaoxon and paraoxon) are active forms and are subsequently hydrolyzed into inactive metabolites. Elimination of organophosphorus compounds and its metabolites occur mainly via urine, bile and faeces.

Clinical features of Organophosphorus Poisoning

Following exposure to organophosphorus compounds, the toxic features are usually obvious within 30 minutes to 3 hours. This may be delayed in some cases depending on the rate and amount of systemic absorption. The majority of patients give a history of intentional or accidental ingestion of organophosphorus compounds. Toxicity is produced by the rapid absorption of the compound through the gastrointestinal, respiratory tracts and skin.



The clinical symptoms and signs are non-specific and will depend on the specific agent, the quantity and the route of entry. Some patients present with vomiting, diarrhoea and abdominal pain, whilst others may be unconscious on arrival at the hospital. A high index of suspicion is therefore needed to make an early diagnosis. The clinical features can be broadly classified as secondary to the (a) muscarinic effects (b) nicotinic effects and (c) central receptor stimulation.[5] Early cases present predominantly with parasympathetic over-activity, and a characteristic garlic smell. The end result may be a multi-system manifestation involving the gastrointestinal, respiratory, cardiovascular and nervous systems, as well as involvement of skeletal muscle, other organs and metabolic effects such as hypo- or hyperglycemia. Most fatalities occur within 24 hours and those who recover usually do so within 10 days.

Cardiac manifestations

The commonest cardiac manifestations following poisoning are hypotension (with warm, dilated peripheries), and bradycardia. Patients seldom present with tachycardia and hypertension due to predominant nicotinic receptor blockade. Cardiac manifestations are often the cause of serious complications and fatality. Electrocardiographic manifestations include prolonged Q-Tc intervals, elevation of the ST segment, inverted T waves and a prolonged PR interval. There may also be rhythm abnormalities such as sinus bradycardia , ventricular extra-systoles, ventricular tachycardia and fibrillation. Ludomirsky et al 6 described three phases of cardiac toxicity following organophosphate poisoning:

- **Phase I**: A brief period of increased sympathetic tone

Table 1. Symptoms and signs of organophosphorus poisoning

Muscarinic receptors	Nicotinic receptors	Central receptors
Cardiovascular	**Cardiovascular**	**General effects**
● Bradycardia	● Tachycardia	● Anxiety
● Hypotension	● Hypertension	● Restlessness
Respiratory	**Musculoskeletal**	● Ataxia
● Rhinorrhoea	● Weakness	● Convulsions
● Bronchorrhoea	● Fasciculations	● Insomnia
● Bronchospasm	● Cramps	● Dysarthria
● Cough	● Paralysis	● Tremors
Gastrointestinal		● Coma
● Nausea/vomiting		● Absent reflexes
● Increased salivation		● Respiratory depression
● Abdominal cramps		● Circulatory collapse
● Diarrhoea		
● Faecal incontinence		
Genitourinary		
● Urinary continence		
Eyes		
● Blurred vision		
● Increased lacrimation		
● Miosis		
Glands		
● Excessive salivation		

- **Phase II**: A prolonged period of parasympathetic activity including AV node blockade
- **Phase III**: Q-T prolongation followed by torsade de pointes, ventricular tachycardia and ventricular fibrillation.

The mechanism of cardiac toxicity is unclear and the following have all been postulated:

- A direct toxic effect on the myocardium
- Overactivity of cholinergic or nicotinic receptors causing haemodynamic alteration
- Hypoxia
- Acidosis
- Electrolyte abnormalities
- High dose atropine therapy (used as treatment for organophosphate poisoning).

Respiratory manifestations

Respiratory manifestations of acute organophosphorus poisoning include bronchorrhoea, rhinorrhoea, bronchospasm and laryngeal spasm. This is due to the action of the organophosphate on muscarinic receptors. The integrity of the airway may be compromised by excessive secretions. The nicotinic effects lead to weakness and subsequent paralysis of respiratory and oropharyngeal muscles. This increases the likelihood of both airway obstruction and aspiration of gastric contents. Finally, central neurological depression may lead to respiratory arrest.

Gastrointestinal manifestations

Symptoms resembling gastroenteritis such as vomiting, diarrhea and abdominal cramps are the first to occur after oral ingestion of an organophosphorus compound.

Neurological manifestations

A large number of patients, following acute exposure to organophosphorus compounds, will require prolonged ventilatory support in the intensive care unit due to neuromuscular weakness. The neurological manifestations have therefore been a primary focus of interest. There has been an emphasis on reducing the incidence of neuro-muscular respiratory failure. Three different types of paralysis are recognized based largely on the time of occurrence and their differing pathophysiology:

- Type I paralysis or acute paralysis
- Type II paralysis or Intermediate syndrome
- Type III paralysis or Organophosphate- induced delayed polyneuropathy

Type I paralysis or acute paralysis is seen during the initial cholinergic phase. This is when large numbers of both muscarinic and nicotinic receptors are occupied by acetylcholine, leading to persistent depolarization at the neuromuscular junction. Clinical features include muscle fasciculation, cramps, twitching and weakness. At this stage the patient may require ventilatory support due to the weakness of the respiratory muscles leading to respiratory depression and arrest.

Type II paralysis or Intermediate syndrome. This was first described in 1974 by Wadia et al[7] as type II paralysis and subsequently termed "The Intermediate Syndrome" by Senanayake[8] This syndrome develops 24-96 hours after the poisoning. Following recovery from the acute cholinergic crisis, and before the expected onset of delayed neuropathy, some patients develop a state of muscle paralysis. The cardinal feature of the syndrome is muscle weakness affecting the proximal limb muscles and neck flexors. There is a relative sparing of the distal muscle group. One of the earliest manifestations in these patients is the inability to lift their head from the pillow (due to a marked weakness in neck flexion). This is a useful test to establish whether or not a patient is likely to develop respiratory muscle weakness. Of the cranial nerves, those supplying the extra-ocular muscles are mostly involved, with a lesser effect on VII and X. This syndrome persists for about 4-18 days and most patients will survive unless infection or cardiac arrhythmias complicate the course.

Type III paralysis or organophosphate- induced delayed polyneuropathy (OPIDP) is a sensory-motor distal axonopathy that usually occurs after ingestion of large doses of an organophosphorus compound.[9-11] The neuropathy presents as weakness and ataxia following a latent period of 2-4 weeks. Initial stimulation causes excitatory fasciculation, which then progresses to an inhibitory paralysis. The cardinal symptoms are distal weakness of the hands and feet. This is often preceded by calf pain, and in some cases, parasthesia of the distal part of the limbs. Delayed CNS signs include tremor, anxiety and coma.

Diagnosis

As there are no clinical features specific to organophosphorus poisoning, diagnosis requires a high index of suspicion. The combination of a history of exposure and the typical clinical features, make the diagnosis of organophosphorus poisoning relatively easy. The history of exposure may be denied by patients who have attempted suicide, or unavailable in unconscious patients. Helpful signs of poisoning include the pungent garlic-like odour of organophosphorus in breath and vomitus, miosis, bradycardia and muscle fasciculations. Excessive salivation, excessive respiratory tract secretions and lacrimation are other helpful signs. It should be remembered that some patients may present with the nicotinic effects of tachycardia, hypertension and mydiasis (rather that the anticipated bradycardia and hypotension).

Treatment is initiated immediately on clinical suspicion, without waiting for blood investigations (although these are important, to confirm the diagnosis, and rule out multiple poisonings and other metabolic causes of an altered neurological state). Both true and pseudocholinesterase levels can be estimated to assess poisoning. These levels are markedly reduced in organophosphorus poisoning. While true cholinesterase correlates with the severity of poisoning at presentation, pseudocholinesterase levels do not. A 25% or greater reduction in true cholinesterase level is indicative of organophosphorus poisoning.

Management

Decontamination

Skin decontamination is very important step that should never be neglected or hurried. The patient should be removed from the site of exposure and their clothes removed. The patient's body should then be thoroughly washed with soap and water to prevent further absorption from the skin. Prior to treating the patient, staff should be protected from the organophosphate by wearing gloves, gowns and eye protectors. Gastric emptying should then be considered if the patient presents within 1 hour of ingestion. Gastric lavage is the only means of emptying the stomach in unconscious patients in which case the airway needs to be protected. The patient should receive activated charcoal 0.5-1 gm/ kg every four hours to promote adsorption in the gastrointestinal tract. Lavage is preferred to enforced emesis as this may precipitate seizures.

Management of Organophosphorus compunds poisoning

- Skin decontamination
- Airway protection if indicated
- Gastric lavage
- Activated charcoal 0.5-1gm/kg every 4hr
- Anticholinesterase: Atropine/glycopyrrolate
- Cholinesterase reactivator: Pralidoxine
- Ventilatory support
- Inotropic support
- Feeding-enteral/parental

Airway and respiration

The airway should be secured and adequate oxygenation ensured. This is important as atropine can precipitate ventricular fibrillation in hypoxic patients. Paradoxically, the early use of adequate atropine will dry respiratory secretions, improve muscle weakness and thereby improve oxygenation. Careful observation of the respiratory status is required as these patients are prone to develop respiratory failure during both the acute phase and the intermediate syndrome. The following should be monitored on a regular basis to assess the patient's respiratory status:

- Respiratory rate
- Tidal volume/ vital capacity
- Neck muscle weakness
- Ocular muscle involvement eg. diplopia
- Arterial blood gas analysis

Cardiac monitoring

As mentioned earlier, a wide range of cardiac manifestations can occur and careful haemodynamic and electrocardiac monitoring should be undertaken in all patients. It should be remembered that hypoxaemia, metabolic and electrolyte abnormalities can all contribute to cardiac arrhythmias. Some arrhythmias may require cardiac pacing.

Anticholinergics

Atropine. Treatment with anticholinergics (to antagonize the muscarinic effects of the organophosphate on the CNS, CVS and gastrointestinal tract), is still the mainstay of treatment, and should be started as soon as the airway is secured. The recommended starting dose of atropine is a 2mg IV bolus. Subsequent doses of 2-5mg every 5-15 minutes should be administered until atropinization is achieved. The signs of adequate atropinization include an increased heart rate (>100 beats/min.), moderately dilated pupils, a reduction in bowel sounds, a dry mouth and a decrease in bronchial secretions. Contrary to earlier belief, total atropinization (fully dilated pupils, absent bowel sounds, heart rate >150 beats/min) is no longer necessary. Satisfactory management involves keeping the patient adequately atropinized without the attendant risks of total atropinization (hyperexcitability, restlessness, hyperpyrexia and cardiac complications). Continuous atropine infusions are used in some centres in doses of 0.02-0.08mg/kg/hr.[13] The dose of atropine required is maximal on day 1 and tends to decrease over the next few days. Atropine does not reverse the skeletal muscle effects.

Glycopyrolate. Some studies have shown that glycopyrrolate is equally effective, with fewer central nervous system side effects and a better control of secretions.[12]

Cholinesterase reactivator

Oximes are nucleophilic agents that re-activate the phosphorylated acetylcholinesterase by binding to the organophosphorus molecule. The use of oximes in acute organophosphorus poisoning has been a controversial subject for the last two decades as there have been very few randomized controlled trials that have addressed the role of pralidoxime (PAM).

Pralidoxime has three main actions:

- A direct reaction converting the organophosphate to a harmless compound.
- A transient reaction protecting the enzyme from further inhibition.
- Reactivation of the inhibited alkyl phosphorylated enzyme to free the active unit (if given early enough)

The reactivating action of pralidoxime is most marked at the nicotinic skeletal neuromuscular junction. It does not reverse the muscarinic manifestations of organophosphorus poisoning. Pralidoxime should be started as early as possible to prevent permanent binding of the organophosphate to acetylcholinesterase. Once this has occurred, receptor regeneration is required to allow recovery. The recommended dose of pralidoxime in organophosphorus poisoning is 1 gram, by intravenous injection, every 6-12 hour in adults (maximum dose 12g/24 hours) and 25-50mg/kg in children. Pralidoxime should be continued until adequate spontaneous ventilation is achieved by the patient. The effective plasma concentration is 4mg/litre and the patient should show signs of improvement 10-40 minutes after its administration. Plasma and pseudocholinesterase levels should ideally be monitored during treatment. Side effects of pralidoxime include drowsiness, visual

disturbances, nausea, tachycardia and muscle weakness, so treatment should be reserved for potentially fatal cases.

Case Insert:

A 20 year old female was bought to the casualty department one hour following the ingestion of an organophosphorus compound.

On arrival, the patient was drowsy with a garlic-like odour from the frothy secretions in her mouth. She had a heart rate of 60 beats/minute, blood pressure of 100/60mmHg and constricted pupils. In order to protect the airway, the trachea was intubated immediately after securing intravenous access. Gastric lavage was performed with normal saline and 50gm of activated charcoal introduced via the Ryle's tube. Atropine 2mg was administered intravenously and repeated every 5 minutes until the pupils dilated, HR increased to >100beats/ minute and secretions from the endotracheal tube decreased. Pralidoxime 1gm was slowly given intravenously. The patient was then transferred to the ICU for ventilatory support and close monitoring.

In the intensive care unit, the patient was sedated with midazolam 1mg/hr and ventilatory support continued. An atropine infusion was started at 4mg/hour but due to copious secretions from both mouth and respiratory tract was increased to 6-8mg/hour. This was gradually reduced and finally stopped on day 10 of her stay in ICU. Pralidoxime 1gm IV was repeated 6 hourly for a week. Her condition deteriorated with the development of pneumonia, which was successfully treated with appropriate antibiotics. A percutaneous dilatational tracheostomy was performed on the 12th day of her ICU stay. weaning from ventilatory support proved difficult due to her pneumonia but on the 17th day after admission, the patient was discharged from ICU to the general ward.

Prevention

Improved regulation of the availability of pesticides, strict regulation of vendors, and modifications in packaging of pesticides may all help reduce the use of organophosphates as poisons. Adequate provision of information to the public, regular training of health care providers, better availability of drugs / antidotes and the establishment of poison information centres will facilitate in reducing the morbidity and mortality related to organophosphorus poisoning. Insecticides should be kept out of reach of children, to prevent accidental poisoning. During agricultural spraying, proper precautions should be taken to prevent inhalation and accidental ingestion of the substance.

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PERIOPERATIVE FLUIDS IN CHILDREN

CM Wilson, Sheffield Children's Hospital

Starvation, surgery and anaesthesia cause stress and alter physiology. Intravenous fluids are administered perioperatively to maintain homeostasis during this period. Water and electrolytes are required to correct deficits and ensure adequate intravascular volume, cardiac output and ultimately tissue oxygen delivery. Calories in the form of dextrose may be needed to prevent hypoglycaemia.

The majority of fit paediatric patients undergoing minor surgery (circumcision, hernia repair) will re-establish oral intake in the early postoperative phase and will not need routine intravenous fluids. Fasting times should be observed so that children are not left without fluid intake for longer that necessary. In elective surgery clear fluids should be allowed up to 2 hours preoperatively but food should not be taken within 6 hours. Breast or formula milk may be given within 4 hours.

Patients undergoing longer or more major procedures, or anyone compromised by underlying problems, will need intravenous fluids. Fluids are given for three reasons:

- **Resuscitation** - to correct pre-existing hypovolaemia or dehydration
- **Maintenance** - to provide water, electrolytes and glucose during the starvation period.
- **Replacement** of ongoing losses due to evaporation from an open wound or via the humidification of dry inspired gases, bleeding, pyrexia, gastrointestinal and third space losses (fluid leak into tissues) during surgery and into the post-operative period.

Resuscitation

The dehydrated or hypovolaemic child should be resuscitated prior to surgery unless the nature of the illness and operation preclude this. In this case rapid correction of hypovolaemia should commence to maintain circulating volume and cerebral perfusion.

Hypovolaemia (losses from the intravascular space) should be replaced initially with boluses of isotonic (0.9%) saline or colloid 20 ml/kg. Blood should be considered if the haemoglobin is low and more than 40 ml/kg of fluid is required.[1]

Dehydration (total body water loss) should be corrected more slowly, preferably, by the oral route if tolerated and time allows, but otherwise intravenously. The rapid rehydration technique advocated by Assadi and Copelovitch[2] describes an initial rapid (1-2 hours) infusion of isotonic saline to correct hypovolaemia. This is followed by a slower correction of dehydration over 24-72 hours with 0.9%, 0.45% or 0.2% saline depending on measured plasma sodium. Too rapid correction of dehydration with hypotonic fluid will result in cerebral oedema secondary to hyponatraemia.

An otherwise healthy child starved preoperatively will have a fluid deficit. This may be calculated by multiplying the hourly maintenance requirement (see table) by the number of hours starved. The deficit can be replaced 50% in the first hour of surgery, and 25% in each of the subsequent two hours.[3] If maintenance fluids are also given, deficits should be corrected using isotonic saline or Hartmanns (Ringers Lactate) solution. This will avoid giving hypotonic fluids at greater than maintenance rates.

Maintenance

Maintenance fluid requirements have been calculated a number of ways including by caloric expenditure and body surface area. The simplest and most commonly used formula was devised by Holliday and Sega[4] and modified by Oh.[5] It relates energy (caloric) expenditure, and therefore volume of fluid required to weight in kg (table 1).

For example a child of

- 9kg requires 4x9 = 36ml/hour
- 18kg requires 40+ (2x8) = 56ml/hour
- 36kg requires 60 + 16 = 76ml/ hour

Electrolyte and glucose requirements were also calculated on a weight basis and an "ideal" solution proposed containing 0.22% NaCl in 5% dextrose (0.18% NaCl in 4% dextrose in the UK) with KCl 20mmol/l. This solution has become the mainstay of maintenance intravenous fluid therapy ever since. However, its use has recently been questioned and the use of isotonic fluid or possibly smaller volumes of hypotonic fluid advocated instead.

Table 1

	Holliday and Segar	Oh
Body weight		
1-10kg	4ml/kg/hour	4ml/kg/hour
10-20kg	40ml/hour + 2ml/kg/hour above 10 kg	20 + (2 x weight in kg) ml/kg/h
>20kg	60ml/hour + 1ml/kg/hour above 20 kg	40 + weight in kg ml/kg/h

Table 2. Paediatric Surgical Unit Guidelines, Sheffield Children's Hospital.

Weight / age	**< 1.0 kg**	**1.0 - 1.5 kg**	**1.5 - 2.0 kg**	**> 2.0 kg**
	Fluid requirement	**ml/kg/day**		
Day 1	100 - 120	80 - 100	60 - 80	40 - 60
Day 2	120 - 150	110 - 130	90 - 110	60 - 90
Day 3	150 - 170	140 - 160	120 - 140	80 - 100
Day 4	180 - 200	160 - 180	140 - 160	100 - 120
Day 5	180 - 200	170 - 200	150 - 180	120 - 150

Neonates (up to 44 weeks post-conceptual age) have a slightly different fluid requirement. They are born physiologically "waterlogged" but then lose up to 10% of their body weight in the first week of life. Initially much smaller maintenance volumes are needed which increase over the next few days. Premature or low birth weight babies have a greater surface area to weight ratio, lose more water by evaporation and consequently require more replacement fluid (table 2). The fluid is usually given as 10% dextrose with or without saline.

An isotonic fluid contains the same concentration of solutes as plasma, and therefore exerts an equal osmotic force. Dextrose is metabolised in blood, so although 5% dextrose solution is isosmolar to plasma, and isotonic in vivo, once metabolised it becomes effectively free water. Dextrose solutions, unless they contain solutes of an equivalent amount to plasma are therefore hypotonic fluids.

Children given hypotonic fluid may become hyponatraemic 6. Ordinarily the kidneys will rapidly excrete a free water load, and homeostasis is maintained. When the body is subjected to stress such as surgery, pain, nausea or hypovolaemia, antidiuretic hormone (ADH) levels rise. Even the relatively mild hypovolaemia of preoperative starvation causes a greater rise in ADH than if supplemental intravenous fluid is given.[7] ADH blocks the renal excretion of water which is therefore conserved, diluting and lowering plasma sodium levels. A rapid or profound drop in sodium results in water moving into cells causing swelling and oedema. This can manifest as raised intracranial pressure, brain stem herniation, coning and death. Prepubertal children in particular are susceptible to brain damage associated with postoperative hyponatraemic encephalopathy. A retrospective analysis of patients with symptomatic hyponatraemia showed a mortality of 8.4%.[8]

Arguments for and against using isotonic fluids for maintenance are laid out by Taylor, Durward and Hatherill.[9, 10] The Royal College of Anaesthetists in conjunction with the Royal College of Paediatrics and Child Health recently issued a statement advising caution in the use of 0.18% saline in 4% dextrose.[11] For these reasons maintenance fluids should be given as at least 0.45% saline, if not always 0.9% saline or Hartmanns solution. Hypotonic fluids should not be administered if the plasma sodium is less than 140mmol/l, although pre-operative measurement may not always be either appropriate or feasible. When the plasma electrolytes are not known it is probably safer (in the short term at least) to give 0.9% saline to a patient with an elevated plasma sodium, than it is to give hypotonic fluids to a hyponatraemic patient.

Dextrose may be required to prevent hypoglycaemia while the child is starved, although this appears to be less of a problem than was previously thought.

The diurnal variation in cortisol levels effects blood glucose levels. These are higher in the morning than the afternoon. Children starved overnight have a higher blood glucose than those starved during the day[12]. The stress response to surgery and starvation results in hyperglycaemia in children as young as 2 weeks of age. This occurs even if no dextrose containing fluids are given.[13] Administration of dextrose will exacerbate this even further.

Recent studies have shown that the per-operative hypoglycaemia is rare in most children. Exceptions to this are neonates less than 48 hours old[14], neonates in whom a pre-operative glucose infusion is interrupted[14] and children below the 3rd centile in weight.[15] These groups of children should be maintained on dextrose infusions without prolonged interruption. The majority of children can be given dextrose free maintenance fluids. An elevated base excess due to lipid mobilisation and ketosis was shown in children given dextrose free Hartmanns solution. This did not occur when dextrose (2% or 5%) in Hartmanns solution was used.[16]

If dextrose is given in theatre, Welborn[17] recommends a 2.5% dextrose infusion as 5% dextrose invariably resulted in moderate to marked hyperglycaemia. Alternatively, glucose requirement may be calculated on a mg/kg/hour basis. Glucose 120mg/kg/hour maintains blood suger within a normal range, and prevents lipid mobilisation.[16] If solutions containing less than 5% dextrose are unavailable, dextrose may be given as a separate infusion or added to a bag of saline or Hartmanns.

Any child perceived to be at risk of hypoglycaemia or hyperglycaemia should have their blood glucose monitored at regular intervals.

Ongoing losses

Measured losses should be replaced with an isotonic fluid e.g normal saline, a colloid, or blood to replace haemorrhage resulting in unacceptably low haemoglobin levels.

Fluid evaporation from an open wound or 3rd space losses vary depending on the operation and may range from 5 up to 20ml/kg/hour.[18] Loss of fluid via the respiratory tract due to humidification of inspired gas may be reduced by using a circle

system or HME (heat and moisture exchange filter) in the breathing circuit.

Blood or other fluid loss is often difficult to measure especially when irrigation fluids are used. For this reason the child's clinical state should be monitored continuously looking at heart rate, capillary refill time and blood pressure. In longer or more complicated cases core-peripheral temperature gradient, urine output (volume and osmolarity) invasive blood pressure and central venous pressure should be measured. In a warm and otherwise stable child with good analgesia a rise in heart rate and prolonged capillary refill time are reliable indicators of fluid loss, while hypotension occurs relatively later when due to hypovolaemia.

Monitoring of vital signs should continue in the post-operative period and fluid loss from the urinary catheter, naso-gastric tube or wound drains measured and replaced promptly. Symptoms of raised intracranial pressure include nausea, vomiting, reduced level of consciousness, respiratory depression and seizures. Nausea, vomiting and drowsiness may be attributed to the side effects of surgery, anaesthesia and analgesia but by the onset of seizures and respiratory depression due to hyponatraemic encephalopathy, it may be too late.

Suggested fluid regime

- Maintenance infusion calculated on weight basis using 0.9% or 0.45% saline.
- Additional fluid to correct deficits, measured or suspected ongoing losses: 0.9% saline, colloid or blood.
- Dextrose if neonate, or measured blood sugar is low at 120mg/kg/hour.

Conclusions

- The majority of fit paediatric patients undergoing minor surgery will re-establish oral intake in the early postoperative phase and will not need routine intravenous fluids.
- Hypotonic fluids should be used with care and must not be infused in large volumes or at greater than maintenance rates.
- Hypovolaemia should be corrected with rapid infusion of isotonic saline, while dehydration is corrected more slowly over 14-72 hours as appropriate.
- Ongoing losses should be measured and replaced.
- Plasma electrolytes and glucose should be measured regularly in any child requiring large volumes of fluid or who remains on intravenous fluids for more than 24 hours.

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Erratum

In Update in Anaesthesia Number 18, the authors of the "The Emergency Management of Poisoning" should have read: Appelboam R and Appelboam A. The editor apologises from this error.

RETAINED PLACENTA: ANAESTHETIC CONSIDERATIONS

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Third stage of labour

The third stage of labour is delivery of the placenta. This is often overlooked because of excitement following the birth of the baby. The retroplacental myometrium must contract to allow the placenta to shear away from its bed and be expelled. Signs of separation are listed in the table below. Retained placenta complicates 2% of deliveries world-wide and is a significant cause of maternal mortality and morbidity. In the developing world the associated mortality approaches 10%. If retention does occur, prompt appropriate treatment can prove life saving.

Table 1. Signs of placental separation
Uterus rises in maternal abdomen
Uterine shape changes from discoid to globular
Umbilical cord lengthens
Vaginal blood loss

Active vs expectant management of third stage

Active management involves administration of oxytocic after delivery followed by early clamping and cutting of the umbilical cord. Controlled cord traction is undertaken with simultaneous suprapubic pressure to prevent inversion of the uterus.

Expectant (also known as conservative or physiological) management means waiting for signs of spontaneous separation (table 1) and delivery of the placenta.

Retained placenta

Drugs that stimulate uterine contraction must be used with caution before the third stage is complete, as the contracting cervix can trap the placenta. The placenta is said to be retained if it has not been delivered within 30 - 60 minutes of the birth. The following are risk factors:

- Previous retained placenta
- Previous injury to uterus
- Pre-term delivery
- Induced labour
- Multiparity

Potential complications

Retained placenta can lead to a number of potentially life threatening complications:

- Primary post partum haemorrhage (and consequent hypovolaemic shock)
- Secondary (delayed) post partum haemorrhage - due to retained placental fragments
- Uterine inversion
- Puerperal sepsis

Initial management

Initial management is expectant. Vaginal examination will establish whether the cervical os is open and if placental retention is due to adherence. If the placenta has separated and is retained because of a closed os then profound analgesia should allow manual dilatation of the cervix and access to the uterine cavity. It should be noted that efforts to separate an adherent placenta might lead to major haemorrhage.

The following steps should then be executed:

- Observe the patient for signs of blood loss e.g. pallor, tachycardia and hypotension. Remember that blood loss can be difficult to estimate and may be concealed.
- Provided vital signs are stable, wait further 30 minutes for spontaneous delivery of the placenta.
- Empty the bladder, vary maternal position and start breast-feeding (to stimulate oxytocin secretion).
- Obtain large bore intravenous access and commence infusion with normal Saline or Hartmann's.
- Take blood for a full blood count (to establish haemoglobin concentration) and a group and antibody screen (in case blood transfusion proves necessary).

If these non-invasive measures fail, or significant haemorrhage supervenes then further steps will be required.

Medical therapies

Non-surgical strategies may be useful in rural areas where access to the skills required for manual removal of placenta may be limited. A Cochrane review has examined the rather limited efficacies of umbilical venous injection of saline, plasma expander, oxytocin and prostaglandin. Nitrate compounds such as nitroglycerine produce uterine smooth muscle relaxation of rapid onset and short duration. They can potentially obviate the need for anaesthesia. Women should be warned that they may experience a transient headache (cerebral vasodilatation) or dizziness (hypotension) following administration of nitrates. Systemic vasodilatation may require correction with i.v. fluids and/or vasopressors. Nitroglycerine can be given by sublingual spray 800micrograms = 2 (400microgram puffs) or i.v. bolus 100 - 200micrograms.

Surgical management

Manual removal of the placenta is the standard treatment and is

usually carried out under anaesthesia (or more rarely, under sedation and analgesia) (table 2).

All women should be given a non-particulate antacid such as 0.3M sodium citrate 30ml to neutralise gastric contents.

General anaesthesia and sedation

A rapid sequence induction should be performed following adequate pre-oxygenation. If the woman is shocked, etomidate or ketamine are preferable to thiopental or propofol as induction agents. Equipotent doses of all the volatile agents depress uterine contractility to an equivalent, dose-dependent extent. Electrocardiogram, blood pressure and end-tidal CO_2/vapour tension should be monitored if possible.

Sedation and monitoring should ideally be performed by an anaesthetist (or at least a dedicated practitioner who is not involved in the surgical operation). Fentanyl, midazolam and ketamine can all be given by titrated i.v. increments.

Regional anaesthesia

Spinal anaesthesia avoids the risks associated with general anaesthesia. 2.0 - 2.5ml of hyperbaric bupivacaine 0.5% should ensure cold sensation blockade to T6 and maternal intra-operative comfort. Hypotension secondary to regional anaesthesia is likely to be related to maternal blood loss rather than block height.

Table 2. Comparison of general anaesthesia, regional anaesthesia and sedation

Technique	Advantages	Disadvantages
GA	Dose-dependent uterine relaxation by volatile agent.	Risks of general anaesthesia e.g. airway compromise, aspiration, anaphylaxis.
Spinal	Rapid establishment of profound analgesia. Avoids risks of GA.	Potential for sudden hypotension if extent of haemorrhage not recognised.
Epidural	Good if already in situ	Takes time to establish de novo
Sedation	Quick and easy	Poor uterine relaxation Unprotected airway: risk of aspiration if overdose

A low-dose spinal anaesthetic regimen comprising 1.5ml 0.25% plain bupivacaine and fentanyl 25micrograms has been shown to provide satisfactory operative conditions. Motor function was preserved, and maternal satisfaction was high.

Antibiotics and oxytocics

Following retained placenta there is an increased incidence of endometritis (caused by a variety of organisms). However, there is no consensus opinion on whether antibiotic prophylaxis is routinely indicated. Syntocinon(r) 40i.u. in 500ml N Saline should be infused over 4 hours as prophylaxis against atonic postpartum haemorrhage.

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SUXAMETHONIUM APNOEA

JE Rees, Exeter, UK.

Introduction

Suxamethonium (succinylcholine) apnoea occurs when a patient has been given the muscle relaxant suxamethonium, but does not have the enzymes to metabolise it. Thus they remain paralysed for an increased length of time and cannot breathe adequately at the end of an anaesthetic.

This article describes the action of suxamethonium, the inheritance of suxamethonium apnoea, and the non-inherited conditions that can also cause it. The presentation and treatment of the condition are discussed. The post-operative care of patients and their families is outlined. Finally mivacurium, a short-acting, non-depolarising muscle relaxant, which can cause similar problems, is discussed with a case report.

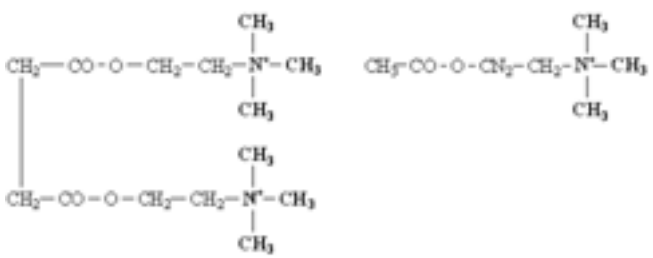
Suxamethonium

Suxamethonium is a depolarising muscle relaxant, which has the fastest onset of all the muscle relaxants. Its length of action is 2-6 minutes. It acts by mimicking acetylcholine at the neuromuscular junction and binds to the post-synaptic membrane of the junction thus preventing acetylcholine from binding. It is an example of non-competitive binding. Unlike non-depolarising muscle relaxants, it cannot be reversed, and recovery is spontaneous. Suxamethonium is mainly metabolised by plasma cholinesterase (previously called pseudo-cholinesterase) and the kidneys excrete 10%. Anticholinesterases such as neostigmine prolong the action of suxamethonium by inhibiting plasma cholinesterases and so should not be given with suxamethonium.

The structure of suxamethonium and acetylcholine.

The two nitrogen-containing groups (**shown in bold**) bind to the alpha (α) subunit of the post-synaptic acetylcholine receptor at the neuromuscular junction. This causes an ion channel to open in the post-synaptic membrane and depolarisation of the muscle and fasciculations (visible muscle twitches) to occur. The suxamethonium stays bound to the membrane: it remains depolarised and further action potentials cannot pass to the muscle. All muscles go flaccid, which facilitates intubation. The action of suxamethonium is terminated by plasma cholinesterase.

Figure 1: The structure of suxamethonium and acetylcholine



Suxamethonium *Acetylcholine*

Spontaneous breathing cannot occur until the action of suxamethonium has ceased.

The indications for suxamethonium

Suxamethonium is used to intubate patients rapidly. This is useful in patients who have full stomachs as in an emergency or for the treatment of laryngospasm. The dose used is 1.0 - 1.5mg/kg. If more than one dose is given the heart rate may slow. In children this can occur with the first dose. This can be prevented and treated by intravenous atropine.

Suxamethonium in these situations is useful because it acts and wears off quickly. If a patient has been adequately pre-oxygenated for 3 minutes, and proves impossible to intubate, the patient can be turned on their side and spontaneous respiration rapidly regained. Patients with suxamethonium apnoea do not recover muscle function rapidly after suxamethonium.

Suxamethonium apnoea

Suxamethonium apnoea is rare. It can be inherited, or it can appear spontaneously in a person with no family history. In cases where suxamethonium apnoea is inherited the level of plasma cholinesterase is reduced. In the acquired condition the level of plasma cholinesterase is normal but its activity is reduced.

Inherited suxamethonium apnoea

The genes for the inheritance of plasma cholinesterase are autosomal. There are several variations from the normal enzyme $E1^U$. The most common of these is $E1^a$. This abnormal gene is carried by 4% of the Caucasian population. This figure is higher in Asians and those from the Middle East and lower in Africans [1,2]. People who are heterozygous for the genes ($E1^uE1^a$) have an increased recovery time from suxamethonium (approximately 30 minutes). Homozygotes ($E1^aE1^a$) have reduced functioning of plasma cholinesterase and can take 2 hours or more to recover from suxamethonium. There are other more rare abnormal enzyme genes such as $E1^f$ (the fluoride plasma cholinesterase) and $E1^s$ (the silent). In $E1^s$ there is little plasma cholinesterase activity and therefore recovery from suxamethonium can take over 3 hours. In these people non-specific plasma esterases help to clear suxamethonium from the blood. There are ethnic differences in the silent type atypical enzyme ($E1^s$). Studies have suggested that this gene is more common in Asian populations.

Acquired Suxamethonium apnoea

Plasma cholinesterase is normal in these subjects, but activity is reduced. Acquired suxamethonium apnoea can occur in the following situations;

- Pregnancy
- Hypothyroidism
- Liver disease
- Renal disease

- Carcinomatosis
- Cardiopulmonary bypass
- Anticholinesterases
- Monoamine oxidase inhibitors
- Methotrexate

In these cases the action of suxamethonium is lengthened by minutes rather than hours.

Presentation of suxamethonium apnoea

Suxamethonium apnoea is not usually apparent until it is time to wake the patient up. At the end of the procedure the patient makes little effort to cough or breathe spontaneously. The pulse rate and blood pressure rise. Patients may sweat and the pupils may dilate. This occurs because the patient becoming aware but is still paralysed. At this stage a nerve stimulator (if available) can be used to determine whether the patient is still paralysed. If the patient is still paralysed but unable to move they should be re-anaesthetised.

Treatment of suxamethonium apnoea

The patient should be anaesthetised and ventilated. Neuromuscular transmission should be monitored with a nerve stimulator. As the suxamethonium wears off they should regain four strong twitches with no fade when tested with a nerve stimulator using a "train of four" (set at 2Hz over 2 seconds). If a nerve stimulator is not available then the patient should be kept anaesthetised until they are breathing spontaneously. The patient may have experienced a phase of awareness in the initial waking phase, and will need to have this explained to them when they are fully recovered. The patient should remain ventilated and anaesthetised until breathing spontaneously. They should be extubated awake when they are able to obey commands, can grip tightly and raise their head off the pillow for 10 seconds. Do not be tempted to extubate them deeper or earlier than this, as they may become tired quickly and might need reintubation.

Case Report

A 72 year old lady was admitted for direct laryngoscopy under the ENT surgeons. She had possessed a hoarse voice for a number of months and a vocal cord nodule had been seen on indirect laryngoscopy and needed removing. She had undergone many anaesthetic procedures in the past with no problems. None of these were as emergencies. As this was a short procedure but required full paralysis she was given mivacurium. The procedure went well and took 12 minutes. Neostigmine was given to reverse the mivacurium. The anaesthetic gases and ventilator were stopped. Her pulse rate began to rise to 100 beats per minute and her blood pressure rose from 90/60 to 160/100. She was visibly sweating. She had made no effort to breathe spontaneously. Nerve function was tested using a peripheral nerve stimulator. There were no twitches. It was concluded that she was still paralysed and she was re-anaesthetised and put back on a ventilator. She was taken to recovery where she was monitored closely. She began to breathe spontaneously and was finally taken off the ventilator 2 hours later. Blood tests later revealed that she had very low levels of plasma cholinesterases. She is undergoing genetic tests but the levels are so low it is suspected she is a homozygote for the abnormal plasma cholinesterase genes. Her family is also being tested.

This lady now has a red triangle on the front of her notes and her and her GP have been informed that she is to avoid suxamethonium (and mivacurium) in the future.

Post-operative care of patient and families

If a person has had an episode of suxamethonium apnoea then they ought to be warned to avoid suxamethonium in the future. A warning card can be carried by the patient to show doctors in the future. It must be explained that this condition can be inherited and if available both the patient and their direct family should have a blood test to measure the level of plasma cholinesterases to confirm whether they have the inherited form or the acquired. The method for detecting structurally abnormal plasma cholinesterases was first described by Kalow and Genest in 1957. If the plasma of normal patients is added to a benzoylcholine solution light is emitted at a specific wavelength, which can be measured. If dibucaine is also added no light is emitted as the reaction is inhibited. The inhibition of light production is given as a percentage and referred to as the dibucaine number. A normal patient has a number of 77-83. Hetrozygotes for the abnormal plasma cholinesterase gene have a number of 45-68. Homozygotes (both genes abnormal) have a number of less than 30. In this way the patient and the family can all be tested.

Mivacurium

This is the shortest-acting non-depolarising muscle relaxant available. It is relatively new and therefore expensive. Its advantages over suxamethonium are that it does not cause muscle pains after administration. It can be used for short procedures that require full muscle relaxation for airway manipulation such as ENT surgery. It cannot be used in emergency cases to allow rapid intubation (as in a rapid sequence induction), because its time of onset is slow, like most other non-depolarising muscle relaxants. It is metabolised by plasma cholinesterase (like suxamethonium). As non-depolarising muscle relaxants like mivacurium bind **competitively** with the postsynaptic membrane of the neuromuscular junction, they can be reversed with anticholinesterase drugs such as neostigamine. Anticholinesterases increase the concentration of acetylcholine at the neuromuscular junction and therefore facilitate reversal of the blockade. If decreased levels of plasma cholinesterase are either inherited or acquired (as discussed above) the length of action of mivacurium is increased as with suxamethonium apnoea.

Thank you to Dr John Saddler, Consultant Anaesthetist, for proof reading this article.

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TETANUS: A REVIEW

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Tetanus remains an important cause of death worldwide and is associated with a high mortality, particularly in the developing world. With modern intensive care management, death from acute respiratory failure should be prevented, but cardiovascular complications as a result of autonomic instability and other causes of death remain.1 In this article, the pathophysiology, clinical features, and current management of tetanus are reviewed.

In spite of the World Health Organization's intention to eradicate tetanus by the year 1995, it remains endemic in the developing world. The WHO estimated that there were approximately 1,000,000 deaths from tetanus worldwide in 1992. This included 580,000 deaths from neonatal tetanus, of which 210,000 were in South East Asia and 152,000 in Africa. The disease is uncommon in developed countries. In South Africa approximately 300 cases occur each year (6 per million head of population), approximately 12-15 cases are reported each year in Britain (0.2 per million) and between 50 and 70 in the USA (0.2 per million).

Tetanus is caused by a Gram-positive bacillus, Clostridium tetani. This is a common bacterium with a natural habitat in the soil. It can also be isolated from animals and human faeces. It is a motile, spore-forming obligate anaerobe. The spore is incompletely destroyed by boiling but eliminated by autoclaving at[1] atmosphere pressure and 120^{o}C for 15 min. It is rarely cultured, as the diagnosis of the disease is clinical. Clostridium tetani produces its clinical effects via a powerful exotoxin. The role of the toxin within the organism is not known. The DNA for this toxin is contained in a plasmid. Presence of the bacterium does not always mean that the disease will occur, as not all strains possess the plasmid. Bacterial antimicrobial sensitivity has been little investigated.

As infection does not confer immunity, prevention is through vaccination. Tetanus vaccine has been available since 1923. Vaccination is started at 2 months of age with three injections performed at monthly intervals. The second injection confers immunity with the third prolonging its duration. A booster is given before the age of 5. Similar responses occur in older children and adults. Neonatal immunity is provided by maternal vaccination and transplacental transfer of immunoglobulin. This may be impaired in the presence of maternal HIV infection. Immunity is not life-long. Revaccination at 10-yr intervals is recommended in the USA. In the UK, two boosters spaced 10 years apart are recommended in adulthood, so the recommendations do not extend to vaccination beyond the third decade. Thus in the UK, after the 5 injections patients are considered immune, and there is no value in giving further prophylactic doses. In the USA, more than 70% of cases and 80% of deaths occur in those over 50. Similar proportions are reported in Europe.

PATHOPHYSIOLOGY

Under anaerobic conditions found in necrotic or infected tissue, the tetanus bacillus secretes two toxins: tetanospasmin and tetanolysin. Tetanolysin is capable of locally damaging viable tissue surrounding the infection and optimizing the conditions for bacterial multiplication.

Toxins

Tetanospasmin leads to the clinical syndrome of tetanus. It binds to neural membranes and the amino terminus facilitates cell entry. It acts pre-synaptically to prevent neurotransmitter release from affected neurones. Released tetanospasmin spreads to underlying tissue and binds to gangliosides on the membranes of local nerve terminals. If toxin load is high, some may enter the bloodstream from where it diffuses to bind to nerve terminals throughout the body. The toxin is then internalized and transported intra-axonally and retrogradely to the cell body. Transport occurs first in motor and later in sensory and autonomic nerves. Once in the cell body the toxin can diffuse out, affecting and entering nearby neurones. When spinal inhibitory interneurones are affected, symptoms occur. Further retrograde intraneural transport occurs with toxin spreading to the brainstem and midbrain. This passage includes retrograde transfer across synaptic clefts by a mechanism that is unclear.

Toxins and the CNS

The effects of the toxin result from prevention of neurotransmitter release. Synaptobrevin is a membrane protein necessary for the export of intracellular vesicles containing neurotransmitter. The tetanospasmin cleaves synaptobrevin, thereby preventing neurotransmitter release. The toxin has a predominant effect on inhibitory neurones, inhibiting release of glycine and gamma-aminobutyric acid (GABA). The term "disinhibition" is used as the main effect of tetanus. This results in a failure of inhibition (relaxation) of muscle groups leading to increased muscle tone and muscular spasms because the muscles are unable to relax. In normal muscles, when one muscle group contracts there has to be a corresponding relaxation of the opposing muscle group. In tetanus this is prevented and results in intermittent spasms. Interneurones inhibiting alpha motor neurones are first affected and the motor neurones lose inhibitory control. Later (because of the longer path), pre-ganglionic sympathetic neurones in the lateral horns and the parasympathetic centres are also affected. Motor neurones are similarly affected and the release of acetylcholine into the neuromuscular cleft is reduced. This effect is similar to the action of the closely related botulinum toxin, which produces a flaccid paralysis. However, in tetanus the disinhibitory effect on the motor neurone overwhelms any diminution of function at the neuromuscular junction. Medullary and hypothalamic centres may also be affected. Tetanospasmin has a cortical convulsant effect in animal studies. Whether these

mechanisms contribute to intermittent spasm and autonomic storms is unclear. The pre-junctional effect on the neuromuscular junction may lead to considerable weakness between spasms, and might account for both the paralysis of cranial nerves observed in cephalic tetanus, and myopathies observed after recovery.

Uncontrolled disinhibited efferent discharge from motor neurones in the spinal cord and brainstem leads to intense muscular rigidity and spasm, which may mimic convulsions. The reflex inhibition of antagonist muscle groups is lost, and agonist and antagonist muscles contract simultaneously. Muscle spasms are intensely painful and may lead to fractures and tendon rupture. Muscles of the jaw, face, and head are often involved first because of their shorter axonal pathways. The trunk and limbs follow but peripheral muscles in the hands and feet are relatively spared (Figure 1)

Disinhibited autonomic discharge leads to disturbances in autonomic control, with sympathetic overactivity and excessive plasma catecholamine levels. Neuronal binding of toxin is thought to be irreversible. Recovery requires the growth of new nerve terminals, which explains the prolonged duration of tetanus.

CLINICAL FEATURES

Tetanus usually follows a recognized injury. Contamination of wounds with soil, manure, or rusty metal can lead to tetanus. It can complicate burns, ulcers, gangrene, necrotic snakebites, middle ear infections, septic abortions, childbirth, intramuscular injections, and surgery. Injuries may be trivial, and in up to 50% of cases the injury occurs indoors and/or is not considered serious enough to seek medical treatment. In 15-25% of patients, there is no evidence of a recent wound.

Presentation

There is a clinical triad of rigidity, muscle spasms and autonomic dysfunction. Neck stiffness, sore throat, and difficulty opening the mouth are often early symptoms. Masseter spasm causes trismus or 'lockjaw'. Spasm progressively extend to the facial muscles causing the typical facial expression, 'risus sardonicus', and muscles of swallowing causing dysphagia (figure 1). Rigidity of the neck muscles leads to retraction of the head. Truncal rigidity may lead to opisthotonos, which is the severe arching of the back during a spasm caused by the stronger extensor muscle group. Respiratory difficulty with decreased chest wall compliance may also ensue.

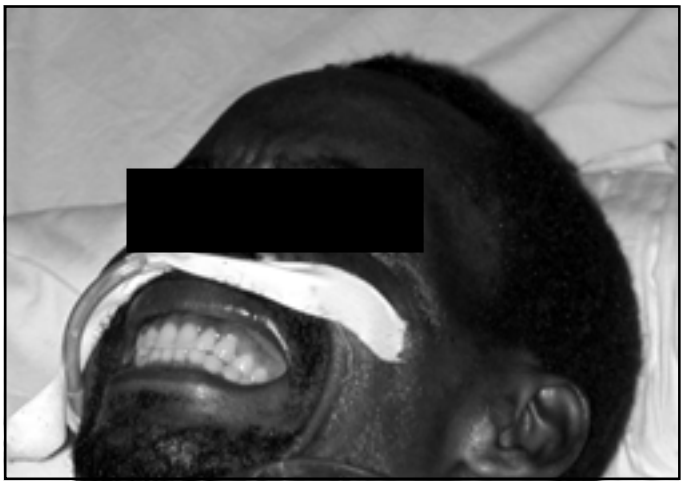

Figure 1.

In addition to increased muscle tone, there are episodic muscular spasms. These tonic contractions have a convulsion-like appearance affecting agonist and antagonist muscle groups together. They may be spontaneous or triggered by touch, visual, auditory or emotional stimuli. Spasms vary in severity and frequency, but may be strong enough to cause fractures and tendon avulsions. Spasms may be almost continual, leading to respiratory failure. Pharyngeal spasms are often followed by laryngeal spasms and are associated with aspiration and life-threatening acute airway obstruction.

Generalized tetanus, the commonest form of tetanus affects all muscles throughout the body. The muscles of the head and neck are usually affected first with progressive caudal spread of rigidity and spasm to affect the whole body. The differential diagnosis includes orofacial infection, dystonic drug reactions, hypocalcaemia, strychnine poisoning, and hysteria.

Local tetanus is seen with lower toxin loads and peripheral injuries. Spasm and rigidity are restricted to a limited area of the body. Mortality is greatly reduced. An exception to this is cephalic tetanus when localized tetanus from a head wound affects the cranial nerves; paralysis rather than spasm predominates at presentation (figure 2) but progression to generalized tetanus is common and mortality is high.

Tetanus neonatorum causes more than 50% of deaths from tetanus worldwide but is very rare in developed countries. Neonates present within a week of birth with a short history of failure to feed, vomiting, and 'convulsions'. Seizures, meningitis, and sepsis are differential diagnoses. Spasms are generalized and mortality is high. Poor umbilical hygiene is the cause of the disease but it is entirely preventable by maternal vaccination, even during pregnancy.

Autonomic effects

Prior to the introduction of artificial ventilation, many patients with severe tetanus died from acute respiratory failure. With the development of intensive care and the ability to ventilate patients it became apparent that severe tetanus was associated with marked autonomic instability. The sympathetic nervous system is most prominently affected. Clinically, increased sympathetic tone causes persistent tachycardia and hypertension. Marked vasoconstriction and pyrexia are also seen. Basal plasma catecholamine levels are raised. 'Autonomic storms' occur with marked cardiovascular instability. Severe hypertension and tachycardia may alternate with profound hypotension, bradycardia, or recurrent cardiac arrest. These alterations are a result of rapid alterations in systemic vascular resistance, rather than problems with cardiac filling or performance. During these 'storms' plasma catecholamine levels are raised up to 10-fold, to levels similar to those seen in phaeochromocytoma. Norepinephrine (noradrenaline) is affected more than epinephrine (adrenaline). Neuronal hyperactivity rather than adrenal medullary hyperactivity appears to predominate.

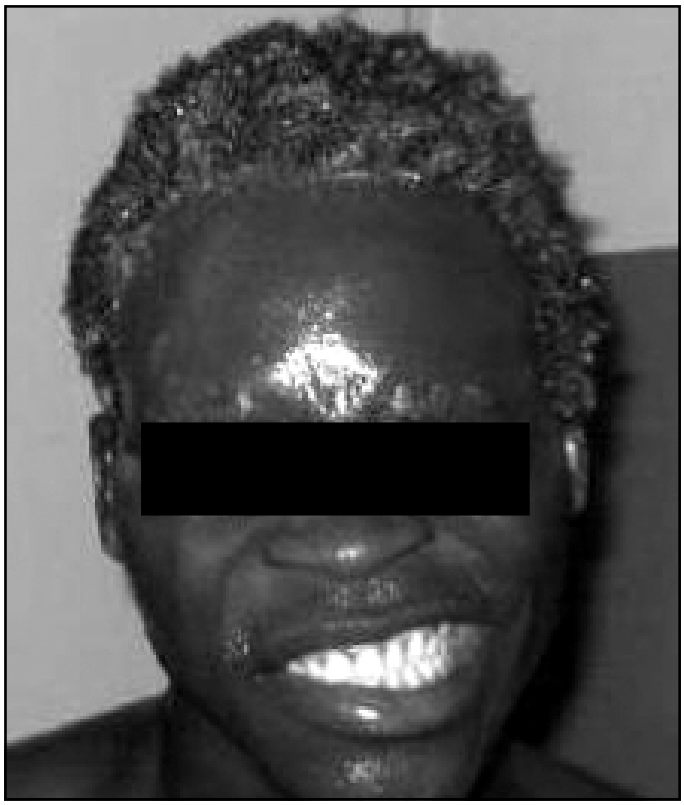

Figure 2

In addition to the cardiovascular system, other autonomic effects include profuse salivation and increased bronchial secretions. Gastric stasis, ileus, diarrhoea, and high output renal failure may all be related to autonomic disturbance.

The involvement of the sympathetic nervous system is established. The role of the parasympathetic system is less clear. Tetanus has been reported to induce lesions in the vagal nuclei, while locally applied toxin may lead to excessive vagal activity. Hypotension, bradycardia, and asystole may arise from increased vagal tone and activity.

Natural history

The incubation period (time from injury to first symptom) averages 7-10 days, with a range of 1-60 days. The onset time (time from first symptom to first spasm) varies between 1-7 days. Shorter incubation and onset times are associated with more severe disease. The first week of the illness is characterized by muscle rigidity and spasms, which progressively increase in severity. Autonomic disturbance usually starts several days after the spasms, and persists for 1-2 weeks. Spasms reduce after 2-3 weeks, but stiffness may persist considerably longer. Recovery from the illness occurs because of re-growth of axon terminals and by toxin destruction.

SEVERITY GRADING

There are several grading systems but the system reported by Ablett is most widely used (table 1).

Table 1: Ablett classification of tetanus severity

Grade	Clinical Features
1	Mild: mild trismus, general spasticity, no respiratory embarrassment, no spasms, no dysphagia.
2	Moderate: moderate trismus, rigidity, short spasms, mild dysphagia, moderate respiratory involvement, respiratory rate > 30, mild dysphagia.
3	Severe: Severe trismus, generalized spasticity, prolonged spasms, respiratory rate > 40, severe dysphagia, apnoeic spells, pulse > 120.
4	Very severe: grade 3 with severe autonomic disturbances involving the cardiovascular system.

Altered cardiovascular physiology

In uncomplicated tetanus, the cardiovascular system mimics that of a normal patient undergoing intense exercise. There is a hyperdynamic circulation largely because of increased basal sympathetic activity and muscle metabolism, with a lesser effect from raised core temperature. There is low-normal systemic vascular resistance and raised cardiac output, because of extensive vasodilatation in metabolically active muscles. As the oxygen extraction ratio does not alter in tetanus, the increased demand must be delivered by increased blood flow. Poor spasm control exaggerates these effects. In severe tetanus, patients are less able to increase cardiac performance and are more susceptible to profound hypotension and shock during acute vasodilatory storms. The mechanism is unclear but may relate to sudden reduction of catecholamine secretion or a direct action of tetanus toxin on the myocardium. Altered myocardial function may occur due to persistently raised catecholamine levels, but abnormal function may occur even in the absence of sepsis or high catecholamine levels.

Altered respiratory physiology

Muscular rigidity and spasms of the chest wall, diaphragm, and abdomen lead to a restrictive defect. Pharyngeal and laryngeal spasms predict respiratory failure or life-threatening airway obstruction. Poor cough from rigidity, spasms, and sedation leads to atelectasis and the risk of pneumonia is high. The inability to swallow copious saliva, profuse bronchial secretions, pharyngeal spasms, raised intra-abdominal pressure, and gastric stasis all increase the risk of aspiration, which is common. Ventilation/perfusion mismatch is also common. Consequently, hypoxia is a uniform finding in moderate or severe tetanus even when the chest is radiologically clear. When breathing air, oxygen tensions are often between 5.3-6.7kPa (40-50mmHg), with the oxygen saturation commonly falling below 80%. In artificially ventilated patients, increased A-a gradients persist. Oxygen delivery and utilization may be compromised even without super-added lung pathology. Acute respiratory distress syndrome may occur as a specific complication of tetanus. Minute ventilation may be altered by a variety of causes. Hyperventilation may occur because of fear, autonomic disturbance, or alteration in brainstem function. Hypocarbia ($PaCO_2$ 4.0-4.6 kPa (30-35mmHg) is usual in mild to moderate disease. Hyperventilation 'storms' may lead to severe hypocarbia ($PaCO_2$ <3.3 kPa (25mmHg). In severe disease, hypoventilation from prolonged spasms and apnoea occurs. Sedation, exhaustion and altered brainstem function may also lead to respiratory failure. Respiratory drive may be deficient

leading to recurrent life-threatening apnoeic periods.

Altered renal physiology

In mild tetanus, renal function is preserved. In severe disease reduced, glomerular filtration rate and impaired renal tubular function are frequent. Contributory causes of renal failure include dehydration, sepsis, blocking of the renal tubule with myoglobin (as a result of muscle breakdown), and alterations in renal blood flow secondary to catecholamine surges. Renal failure may be oliguric or polyuric. Clinically important renal impairment is associated with autonomic instability and histology is normal or shows acute tubular necrosis.

ADULT TETANUS PROTOCOL

St.Mary's Hospital Lacor Gulu, Uganda

1. Start metronidazole intravenously 500mg three times a day.
2. Give tetanus human immune globulin IM 3,000-6,000 iu if available. If not available Equine ATS 10,000 iu IM.
3. Admit ICU, commence oxygen, IV access and monitoring.
4. Alert surgeon to do radical debridement. Nasogastric tube may be passed during surgery.
5. Slow loading dose diazepam IV to control spasms. Up to about 40mg may be required. Give a loading dose of 5g magnesium sulphate slowly over 20 minutes IV.
6. Start diazepam 10mg 6 hourly and increase to hourly if required. Titrate to symptoms.
7. Start magnesium 2.5g IV 2 hourly and increase to hourly if required. Titrate to symptoms. Stop diazepam if symptoms controlled by magnesium alone.
8. Phenobarbitone up to 200mg IV twice a day for breakthrough spasms using 50mg doses.
9. Tracheostomy if airway compromised by above treatment.
10. Intermittent positive pressure ventilation with muscle relaxants if respiration compromised by treatment or uncontrolled spasms.

MANAGEMENT

Treatment strategies involve three management principles:

- Organisms present in the body should be destroyed to prevent further toxin release
- Toxin present in the body, outside the CNS should be neutralized and
- The effects of toxin already in the CNS should be minimized.

Removal of the source of infection

Where present, obvious wounds should be surgically debrided. The surgeon should be encouraged to perform a radical debridement to eliminate as much of the source of infection as possible. Penicillin has been widely used for many years but is a GABA antagonist and is associated with convulsions. Metronidazole is probably the antibiotic of choice. It is safe and comparative studies with penicillin suggest at least as good results. Erythromycin, tetracycline, chloramphenicol, and clindamycin are all accepted as alternatives.

Neutralization of unbound toxin

If available human tetanus immune globulin 3000-6000 units is given intra-muscularly (IM). If this is not available (which is often the case in the developing world), then anti-tetanus horse serum (ATS) should be given after sensitivity tests, in a dose of 10,000 units IM. All these injections should be administered within 24 hours of the diagnosis.

Control of rigidity and spasms

The principle of management is to prevent spasms and rigidity with the minimal dose of pharmacological agent, so that the side effects of the drugs themselves do not become life-threatening. Obtaining the correct dose of agent cannot be judged without frequent assessment by the clinician especially in the early stages. Clinical symptoms may change rapidly.

Avoidance of unnecessary stimulation is mandatory, but the mainstay of treatment is sedation with a benzodiazepine. Benzodiazepines increase GABA activity, by inhibiting an endogenous inhibitor at the $GABA_A$ receptor. Diazepam may be given by various routes. It is cheap and widely used, but long acting metabolites (oxazepam and desmethyldiazepam) may accumulate and lead to prolonged coma. Doses will vary with individuals but a starting dose of 10mg every 6 hours is usual. Higher doses of 20 or 40mg 6 hourly may be necessary. Midazolam has been used with less apparent cumulation.

Additional sedation may be provided by anticonvulsants, particularly phenobarbitone at a dose of up to 200mg IV twice a day. Phenobarbitone has a GABA agonist effect. However it is a potent respiratory depressant and should be used with caution, starting with low doses of 50mg twice a day.

Phenothiazines, usually chlorpromazine have often been used. However caution is essential to avoid deep depression of protective reflexes and the risk of pulmonary aspiration.

In situations where full intensive care facilities are available, the classical teaching is to proceed to tracheostomy and IPPV when sedation does not control the spasms, or when the necessary doses of sedative produce such deep depression of the airway reflexes or respiration that the patient is no longer safe. However, in many parts of the developing world there is little capacity to perform a tracheostomy or give IPPV. Even if a surgeon is available to perform a tracheostomy, the nursing care demands of a tracheostomy over several weeks puts a major strain on nursing capacity, and is frequently not undertaken without firstly considering other treatment options.

Magnesium sulphate may offer some new hope in this context. In Sri Lanka, Attygalle and Rodrigo[2] reported a series of 40 patients with tracheostomy in which IPPV was avoided by using magnesium sulphate. There has also been a report from the USA

where the need for tracheostomy was avoided through the use of magnesium sulphate[3]. The dose suggested is 1g increasing to 2.5g per hour in the adult following a 5g loading dose. The therapeutic serum magnesium levels were 2-4mmols per litre (normal 1.2mmol per litre). Magnesium is a pre-synaptic neuromuscular blocker. It blocks catecholamine release from nerves and the adrenal medulla. It also reduces receptor responsiveness to released catecholamines, is an anticonvulsant and a vasodilator. It antagonises calcium in the myocardium and at the neuromuscular junction, and inhibits parathyroid hormone release lowering serum calcium. If too large a dose is given, it causes weakness and paralysis with central sedation (although the latter is controversial). Attygalle advises using the presence of patella tendon reflexes as a monitor of a safe serum magnesium level. Hypotension and bradyarrhythmia may occur. It is therefore mandatory to maintain magnesium levels in the therapeutic range. In a report by James and Manson[4], patients with very severe tetanus were studied. In these patients, magnesium was found to be inadequate alone as a sedative and relaxant, but was an effective adjunct in controlling autonomic disturbance. The author's experience of using magnesium to manage severe tetanus in rural Africa has been positive, with good outcomes. The future place of magnesium will require further studies but it offers hopeful new possibilities

Neuromuscular blocking agents and intermittent positive pressure ventilation may be required for a prolonged period when sedation alone is inadequate. Traditionally, the long acting agent pancuronium has been used and it is cheaper than the more modern non-depolarising muscle relaxants. Vecuronium, atracurium and rocuronium have also been used.

Propofol sedation has allowed control of spasms and rigidity without the use of neuromuscular blocking drugs. However, drug levels were closer to anaesthetic than sedative concentrations and mechanical ventilation would be required.

Control of autonomic dysfunction

Many different approaches to the treatment of autonomic dysfunction have been reported. Most are presented as case reports or small case series. There is a lack of comparative or controlled studies. In general, outcome measures have been limited to haemodynamic data, rather than survival or morbidity.

Sedation is often the first treatment. Benzodiazepines, anticonvulsants, and morphine are frequently used. Morphine is particularly beneficial as cardiovascular stability may be achieved without cardiac compromise. Dosages vary between 20 and 180 mg daily. Proposed mechanisms of action include replacement of endogenous opioids, reduction in reflex sympathetic activity and release of histamine. Phenothiazines, particularly chlorpromazine are also used; anticholinergic and -adrenergic antagonism may contribute to cardiovasular stability.

α-adrenergic blocking agents, such as propranolol, were used in the past to control episodes of hypertension and tachycardia, but profound hypotension, severe pulmonary oedema and sudden death were all found to occur, Labetolol, which has combined α and β adrenergic blocking effects has been used, but no advantage over propranolol was demonstrated (possibly because its α activity is much less than its β activity), and mortality remained high. In recent years, the short-acting agent, esmolol, has been used successfully. Although good cardiovascular stability was achieved, arterial catecholamine concentrations remained elevated.

Sudden cardiac death is a feature of severe tetanus. The cause remains unclear but plausible explanations include sudden loss of sympathetic drive, catecholamine-induced cardiac damage and increased parasympathetic tone or 'storms'. Persisting beta blockade could exacerbate these causes because of its negatively inotropic effect or vasoconstrictor activity. This may lead to acute cardiac failure, particularly as sympathetic crises are associated with high systemic vascular resistance and normal or low cardiac output. Isolated use of α-adrenergic block with long acting agents cannot therefore be recommended.

Postganglionic and -adrenergic blocking agents such as bethanidine, guanethidine, and phentolamine have been successfully used with propranolol, along with other similar agents such as trimetaphan, phenoxybenzamine, and reserpine. Disadvantages of this group of drugs are that induced hypotension may be difficult to reverse, tachyphylaxis occurs and withdrawal can lead to rebound hypertension.

The α-adrenergic agonist clonidine has been used orally or parenterally, with variable success. Acting centrally, it reduces sympathetic outflow, thus, reducing arterial pressure, heart rate, and catecholamine release from the adrenal medulla. Peripherally, it inhibits the release of norepinephrine from pre-junctional nerve endings. Other useful effects include sedation and anxiolysis.

Magnesium sulphate has been used both in artificially ventilated patients to reduce autonomic disturbance and in non-ventilated patients to control spasms. The dose suggested is 1g increasing to 2.5g per hour for an adult.

Supportive intensive care treatment

Weight loss is universal in tetanus. Contributory factors include inability to swallow, autonomic induced alterations in gastrointestinal function, increased metabolic rate (due to pyrexia and muscular activity), and prolonged critical illness. Nutrition should therefore be established as early as possible. Enteral nutrition is associated with a lower incidence of complications and is cheaper than parenteral nutrition. Nasogastric tube feeding should be started as soon as possible. In experienced units, percutaneous gastrostomy may be more suitable as a route for feeding.

Infective complications of prolonged critical illness, including ventilator-associated pneumonia, are common in tetanus. Securing the airway early in the disease and preventing aspiration and sepsis are logical steps in minimizing this risk. As artificial ventilation is often necessary for several weeks tracheostomy is usually performed after intubation. In experienced hands the percutaneous dilatational method may be particularly suitable for patients with tetanus. This bedside procedure avoids transfer to and from the operating theatre with the attendant risk of provoking autonomic instability. Prevention of respiratory complications also involves meticulous mouth care, chest physiotherapy, and regular tracheal suction, particularly as salivation and bronchial secretions are greatly increased.

Adequate sedation is mandatory before such interventions in patients at risk of uncontrolled spasms or autonomic disturbance. The balance between physiotherapy and sedation may be difficult to achieve.

Other important measures in the routine management of patients with tetanus (as with any long-term critical illness), include prophylaxis of thromboembolism, gastro-intestinal haemorrhage, and pressure sores. The importance of psychological support should not be underestimated.

Venous access is a major problem when diazepam has been used for many days using peripheral veins. An elective placement of a central or femoral line improves general care and outcomes.

COMPLICATIONS

Complications may occur as a result of the disease (e.g. laryngospasm, hypoxia), or as a consequence of treatment (e.g. sedation leading to coma, aspiration or apnoea; ventilator-associated pneumonia; complications of tracheostomy; acute respiratory distress syndrome). Gastro-intestinal complications include gastric stasis, ileus, diarrhoea and haemorrhage. Cardiovascular complications include tachycardia, bradycardia, hypertension, hypotension and asystole. High output renal failure and oliguric renal failure are reported and thromboembolism and overwhelming sepsis also occur.

MORTALITY AND OUTCOME

Fatality rates and causes of death vary dramatically according to the facilities available. Without doubt the introduction of intensive care treatment will reduce mortality. In developing countries, without facilities for prolonged intensive care and ventilatory support, deaths from severe tetanus exceed 50% with airway obstruction, respiratory failure, and renal failure as prominent causes. A mortality of 10% has been suggested as an acceptable goal in developed countries. Modern intensive care should prevent death from acute respiratory failure, but as a result, in severe cases, autonomic disturbance becomes more apparent. Before ICU care was established about 80% of patients died as a result of early acute respiratory failure. Important complications of ICU care include nosocomial infections (particularly ventilator-associated pneumonia), generalized sepsis, thromboembolism, and gastrointestinal haemorrhage. Mortality varies with patient age. In the USA, mortality in adults below 30yr may approach zero, but in those over 60yr is 52%. In Africa, mortality from neonatal tetanus without artificial ventilation is over 80%.

Severe cases of tetanus generally require ICU admission for approximately 3-5 weeks. Recovery can be expected to be complete, with return to normal function, although some survivors of tetanus may have persistent physical and psychological problems.

CONCLUSION

Tetanus is entirely preventable by vaccination. However it remains a major health problem worldwide. In developed countries, several cases present every year in the elderly and unimmunised population. Mortality in these cases remains high. Prolonged intensive care support may be necessary but most treatment is based on limited evidence. Major therapeutic challenges lie in the control of muscular rigidity and spasms, the treatment of autonomic disturbance and the prevention of complications associated with prolonged critical illness. For the developing world tetanus is a major challenge with a high mortality among all age groups. The use of magnesium to avoid long term ventilation is a hopeful development that will need further evaluation. Return to normal function can be expected in those who survive.

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