

Abstracts of invited lectures held at the annual meeting of the European Association of Cardiothoracic Anaesthesiologists in Athens, Greece, May 27th - 30th, 2009

<i>P. Arnold:</i> Networks in congenital cardiac anaesthesia	254
<i>P. Colson:</i> Postoperative atrial fibrillation	254
<i>J. W. W. Gothard:</i> Re-operation in congenital heart disease	256
<i>C.-J. Jakobsen:</i> Percutaneous valve implantation – The anaesthesiologist’s point of view	258
<i>B. Jungwirth:</i> Neurologic complications after cardiac surgery	260
<i>K. Kiviluoma:</i> Surgery in deep hypothermic circulatory arrest: Still much to study	261
<i>A. Maniatis:</i> Perioperative anemia	261
<i>W. T. McBride:</i> Can we reduce the risks of the high-risk cardiac surgery patient?	263
<i>W. T. McBride:</i> Managing material dependent and independent causes of the inflammatory response during cardiac surgery	267
<i>P. Pouard, M. Bojan, S. Gioanni, P. R. Vouhé</i> Life without aprotinin in pediatric cardiac surgery	268
<i>M. Sentürk:</i> Post-resection pulmonary edema	269
<i>G. Silvay:</i> Thoracic aortic aneurysm: Anesthesiologist’s view 2009	270
<i>L. L. Szegedi:</i> Two-lung and one-lung ventilation in patients with chronic obstructive pulmonary disease: The effects of position and FiO ₂	272
<i>C. von Heymann:</i> Evidence based treatment of bleeding after cardiac surgery	272

Networks in congenital cardiac anaesthesia

P. Arnold

Consultant Cardiac Anaesthetist, Jackson Rees Department of Anaesthesia, Alder Hey Children's Hospital, UK

Cardiac Surgical Services in Europe are provided in a large number of centres. In the UK eleven hospitals currently perform cardiac surgery in children, none with a caseload of more than 500 patients per year (1). Many of the operations we perform are relatively uncommon and have implications for anaesthetic management. This makes it difficult for the individual anaesthetists or anaesthetic groups to refer to a wide previous experience in the management of some specific conditions. Finding ways to work more closely between units, pooling data and collaborative research gives us an opportunity to make use of a larger collective experience.

Looking after patients (adults or children) undergoing surgery for congenital heart disease requires specific skills and knowledge. The anaesthetists caring for these patients come from a range of backgrounds: paediatric anaesthesia, cardiac anaesthesia and paediatric intensive care. Specialist societies with interests in general paediatric anaesthesia, or in adult cardiac anaesthesia have found it difficult to accommodate this sub-specialist interest. The exception to this is the recent innovation of a paediatric/congenital session during the EACTA general meeting.

Two other important developments are:

- The creation of the Cardiac Congenital Anaesthesia Society (CCAS) (2). Began in 2005 this Society now has membership of 500. Whilst currently largely based in North America international membership is growing. Activities have included two educational meetings each year, the setting up of a database of congenital cardiac activity, recommendations on training, and maintenance of a web site. The society has taken part in other society meetings and is cosponsoring a session at the World Congress on Paediatric Cardiology and Surgery (3).
- A more informal group of Paediatric Cardiac Anaesthetists has been established in the UK. This group has recently held its second successful meeting. The group has the intention to invite anaesthetists from outside the UK to participate in future meetings.

A further aspect of such collaboration is the growth of congenital cardiac surgery in countries with less developed and well-funded health systems (4). Ways should be found to allow individuals based in these countries to benefit from and participate in the networks being created.

The objective of this lecture is to inform participants of efforts being made to form such collaborations but also to give an opportunity to discuss their own involvement.

References:

1. <http://www.ccad.org.uk/congenital>
2. <http://www.pedsanesthesia.org/ccas/>
3. <http://www.pccs2009.com/>
4. <http://www.babyheart.org/>

Postoperative atrial fibrillation

P. Colson

Montpellier, France

Incidence of postoperative atrial fibrillation (POAF)

The incidence of POAF is approximately 30% after isolated CABG surgery, 40% after valve replacement or repair and 50% after combined procedures. POAF tends to occur within 2 to 4 days with a peak incidence on postoperative day (POD) 2 (94% POAF occur before POD 6). POAF increases postoperative morbidity, with a 3-fold higher incidence of stroke, which contributes to the increased postoperative mortality (hospital mortality: 6% vs. 3%, 6-month mortality: 9% vs. 4%) (1).

Risk factors and pathophysiology

Among POAF risk factors, some are constitutive and unavoidable, like age (75% increase in the odds of developing POAF for every decade), left atrial volume, chronic obstructive pulmonary disease and obesity (in relation to an increased cardiac output and left ventricle myocardial mass, left atrial enlargement) (2). Other factors are modifiable and possibly avoidable, as ICU severity score, inflammation (SIRS, sepsis), positive water balance, hypokalaemia et hypomagnesaemia, or hypoxemia.

POAF electrophysiology features consist of shortening atrial refractoriness, slowing atrial conduction, both facilitating re-entry (1). Several mechanisms

have been incriminated including autonomic imbalance, inflammation and ischemia-reperfusion, interstitial fluid overload, and hyperglycaemia.

Autonomic imbalance during the post-operative period involves increased sympathetic and parasympathetic activation, and excessive production of catecholamine, that may explain the observed benefit of epidural anaesthesia and analgesia (3).

Inflammation may alter atrial conduction, facilitating re-entry. It has been proven that leukocytosis is an independent predictor for POAF. Besides pericardial inflammation, a genetic predisposition (interleukin-6 promoter gene variant) has been found to be associated with POAF. Both non-steroid (NSAI) and steroid anti-inflammatory treatments have been then advocated to reduce the incidence in POAF. The potential benefit of NSAI drugs or corticoids is balanced by the risk of adverse events (4). More recently, statins have gained interest, through anti-inflammatory action too. CRP correlates with a higher POAF risk and statin given before surgery (within the first week) may prevent the risk of POAF by 60% (5).

Among hydro-electrolytic or metabolic factors, hypokalaemia and hypomagnesaemia are well-known contributors to AF. Interstitial fluid overload is also suspected to induce volume and pressure changes that contribute to neurohumoral environment alteration, all facilitating POAF. Hyperglycaemia is also associated with a higher incidence in POAF and glycaemia control may contribute to lower it (6).

POAF prevention

Besides correction of hydro-electrolytic imbalance, several anti-arrhythmic drugs have been used to prevent POAF. However, only β -blockers show substantial beneficial effect in preventing POAF (60 to 70% reduction) (7). ACCA/AHA/ESC issued guidelines in 2006 (Chest), where, unless contraindicated, treatment with an oral β -blocking drug to prevent POAF has been recommended for patients undergoing cardiac surgery.

Alternatively, preoperative administration of amiodarone can be used to reduce the incidence of AF in patients undergoing cardiac surgery, though the reduction seems to be of less magnitude than with β -blockers (< 50%) and associated with an increased risk of bradycardia and hypotension (9). Nevertheless, in ACCA/AHA/ESC guidelines, amiodarone represents an appropriate prophylactic therapy for patients at high risk for POAF.

POAF treatment

Rhythm control should be preferred to rate control as it reduces time to conversion, prolongs maintenance of sinus rhythm and decreases hospital stay (1).

Electrical cardioversion is mandatory in case of haemodynamic instability, acute heart failure, or myocardial ischemia. Amiodarone is the most effective treatment to restore sinus rhythm; alternatively, sotalol which shares electrophysiologic features with amiodarone can be used, and its action is particularly effective at reducing the ventricular rate.

If rhythm control cannot be obtained, rate control is required to control the ventricular rate. Short acting β -blocker agents are the therapy of choice, particularly in ischemic heart disease. Alternatively, amiodarone is also effective in controlling heart rate, without significant deleterious effect on haemodynamics. Other AV nodal blocking agents, such as the calcium-channel blocker agents (diltiazem, isoptin) can be used, but with an increased incidence of atrioventricular block and low output syndrome, related to the negative chronotropic and inotropic effect (10).

Anticoagulation is required in case of prolonged (> 48 h) and/or frequent POAF episodes, and maintained for 4-6 weeks (atrial stunning) (11). The increased risk of bleeding in the postoperative period should not outweigh the benefits in reducing the risk of stroke. Use of anticoagulation therapy is particularly recommended for high-risk patients, such as those with a history of stroke or transient ischemic attack (1).

References

1. Echahidi N, Pibarot P, O'Hara G, Mathieu P. Mechanisms, prevention, and treatment of atrial fibrillation after cardiac surgery. *J Am Coll Cardiol* 2008; 51: 793-801
2. Mathew JP, Fontes ML, Tudor IC et al. A multicenter risk index for atrial fibrillation after cardiac surgery. *JAMA* 2004; 291: 1720-9
3. Scott N, Turfrey D, Ray D et al. A Prospective randomized study of the potential benefits of thoracic epidural anesthesia and analgesia in patients undergoing coronary artery bypass grafting. *Anesth Analg* 2001; 93: 528-35
4. Halonen J, Halonen P, Jarvinen O et al. Corticosteroids for the prevention of atrial fibrillation after cardiac surgery: a randomized controlled trial. *JAMA* 2007; 297: 1562-7
5. Patti G, Chello M, Candura D et al. Randomized trial of atorvastatin for reduction of post-operative atrial fibrillation in patients undergoing cardiac surgery: results of the ARMYDA-3 (Atorvastatin for Reduction of MYocardial Dysrhythmia After cardiac surgery) study. *Circulation* 2006; 114: 1455-61
6. Lazar H, Chipkin S, Fitzgerald C et al. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. *Circulation* 2004; 109: 1497-1502

7. Crystal E, Garfinkle MS, Connolly SS, Ginger TT, Sleik K, Yusuf SS. Interventions for preventing post-operative atrial fibrillation in patients undergoing heart surgery. *Cochrane Database Syst Rev* 2004
8. Fuster V, Ryden LE, Cannom DS et al. ACC/AHA/ESC 2006 guidelines for the management of patients with atrial fibrillation – executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines. *J Am Coll Cardiol* 2006; 48: 854-906
9. Mitchell LB, Exner DV, Wyse DG et al. Prophylactic Oral Amiodarone for the Prevention of Arrhythmias that Begin Early After Revascularization, Valve Replacement, or Repair: PAPA-BEAR: a randomized controlled trial. *JAMA* 2005; 294: 3093-100
10. Wijeyesundera DN, Beattie WS, Rao V, Karski J. Calcium antagonists reduce cardiovascular complications after cardiac surgery: a metaanalysis. *J Am Coll Cardiol* 2003; 41: 1496-505
11. Singer D, Albers G, Dalen J et al. Antithrombotic and Thrombolytic Therapy: The seventh ACCP conference on antithrombotic therapy in atrial fibrillation. *Chest* 2004; 126: 429-456

Re-operation in congenital heart disease

J. W. W. Gothard

Royal Brompton Hospital, London, UK

Introduction

Re-operative surgery in congenital heart disease may be carried out at any age. In infants and children this is often part of staged procedures such as correction of tetralogy of Fallot following a modified Blalock Tausig (BT) shunt or a completion total cavo-pulmonary connection (TCPC) after a previous Glenn shunt (superior vena cava to pulmonary artery anastomosis). Many patients with congenital heart disease require further surgery as they progress into adult life, however, and this topic will be the main emphasis of this presentation.

Adult congenital heart disease (ACHD)

Approximately 0.6-0.8% of babies are born with some form of congenital heart disease (CHD) and 85% of infants with congenital heart disease will reach adulthood in developed countries. There are over one million cases of ACHD in the USA currently and in the UK it is estimated that an additional 1,600 cases of ACHD (moderate to severe disease) accumulate per year.

In major cardiac centres the majority of surgery carried out in patients with ACHD will be classified as a re-operation. This is because the majority of cardiac

surgery carried out in infancy is not curative, as detailed in a recent review by Warnes (1).

Re-operation is increasingly indicated in a number of situations such as the following:

Pulmonary valve replacement (PVR)

- previous tetralogy of Fallot repair
- previous Ross procedure

Right ventricle (RV) to pulmonary artery (PA) conduit replacement

- Truncus arteriosus
- Pulmonary atresia
- Pulmonary/atresia/Fallot “type”
- Double outlet RV

Re-operation on Aortic valve

- subaortic/valvar/supra-aortic
- Marfan’s
- previous AVR

Revision Fontan-type surgery

Miscellaneous – including arrhythmia surgery

The indications for re-operation have widened over the last decade as there is a growing awareness that early intervention may actually improve prognosis. This is exemplified by the increasing numbers of patients with pulmonary valve incompetence, following earlier Fallot’s tetralogy repair, referred for pulmonary valve replacement (2) and a growing awareness in how to optimally manage ACHD (3).

Risk factors for anaesthesia and surgery

ACHD poses a number of factors which increase the risk of surgery or even prohibit corrective surgery. These include increased pulmonary vascular resistance, chronic cyanosis ventricular dysfunction, arrhythmias and problems of re-sternotomy (4,5).

Problems associated with re-sternotomy

The major problem of a re-operation is re-sternotomy. Additional factors which make management of cardiopulmonary bypass difficult include the presence of aortic regurgitation and/or large aorto-pulmonary collaterals. The presence of a ventricular septal defect also means there is a possibility of air reaching the arterial side of the circulation if a pulmonary artery conduit or the right ventricle is breached surgically on opening the chest.

Cardiac structures, including the aorta, the RV and homograft/artificial conduits are often in close proximity to the posterior aspect of the sternum. The retrosternal space is best assessed from a CT or MRI scan pre-operatively. The proximity of structures to the sternum will then determine surgical strategy. In all cases the groin should be prepared for surgery so that femoral vein to femoral artery cardiopulmonary bypass can be instituted if structures are breached on re-sternotomy. If there is a retrosternal space apparent this would be an acceptable approach but if cardiac structures are immediately adjacent to the sternum it is safer to establish cardiopulmonary bypass via the femoral vessels prior to sternotomy, or at least prepare the femoral artery and vein for cannulation. Cardiopulmonary bypass is then used to support the patient if vascular structures are breached. Blood lost from the sternotomy site can then be returned to the venous reservoir, via pump suckers, as the heart is dissected out.

In the face of catastrophic bleeding it may be necessary to rapidly cool the patient and establish circulatory arrest. Ventricular distension as a result of fibrillation or myocardial dysfunction is a hazard of this technique, but this can potentially be minimized by external cardiac massage or direct venting of the left ventricle. These strategies are rarely required, however.

Anaesthetic management and vascular access

In many respects anaesthetic management differs very little from that used as routine in adults presenting from cardiac surgery. There are, however, a few key differences to consider in the patient with ACHD.

A pre-operative anaesthetic assessment should include the following:

Review

- diagnosis and physiological implications
- planned surgery

Assess

- relevant imaging (re-sternotomy)
- catheter/ECHO data
- rhythm/pacing status
- clotting profile
- renal function
- availability blood/products (NB: 22q deletion)

Consider

- Pure “anaesthetic problems” – **No one else will!**
Eg. difficult intubation, previously recognised problems, co-existing congenital abnormalities (eg left SVC), allergies etc

Induction of anaesthesia can be carried out in the usual manner. I personally do not establish invasive monitoring until the patient is anaesthetised, because of potential problems in this group of patients. After induction central venous line and invasive monitoring lines are inserted and external defibrillator contacts applied. Any permanent pacemaker system should have been checked pre-operatively and it is usual to programme this to fixed rate mode immediately prior to surgery. Anaesthetic vascular access needs to take into account previous surgery and existing anatomy. Considerations include the following:

Arterial monitoring line

- avoid side of previous shunt
- right radial artery for aortic surgery/coarctation
- avoid femoral artery required for CPB

Central venous access

- accurate placement essential (ultrasound guidance)
- Presence of left SVC
- use Femoral vein if Fontan type circulation (small cannula SVC only)
- short line RIJ or LIJ
- large bore catheter for transfusion large sheath
- PA catheter rarely used – TOE preferable intra-op

Weaning from cardiopulmonary bypass

Many, but not all, patients will require some degree of inotropic support to aid separation from cardiopulmonary bypass. The need for support depends to a great extent on pre-operative myocardial function. This may be compromised because of chronic cyanosis, periods of ischaemia at previous surgery and systolic/diastolic dysfunction associated with the patient's presenting condition. In addition a further period of aortic cross-clamping may exacerbate myocardial dysfunction. This can be avoided for right-sided (ie: right ventricle/PA) surgery by operating with a beating heart, provided there are no intra-cardiac shunts present.

Transoesophageal echocardiography (TOE) is invaluable in monitoring the need for inotropic support and the efficacy of surgery, which may, fortunately, provide some immediate physiological benefit.

Haemostasis and chest closure

Haemostasis and management of post-operative coagulopathy provide major challenges to the anaesthetist and surgeon involved in re-operative surgery for ACHD. Once weaning from cardiopulmonary bypass is achieved this is one of the most difficult aspects of the whole operation. Co-operation with the blood transfusion service, availability of blood products and near-patient coagulation testing, combined with meticulous surgery, are essential elements required for a successful outcome.

Outcome

The outcome for surgery in patients with ACHD largely depends on the complexity of the presenting condition. In my own unit overall mortality was 4.4% in 342 patients between 1997-2002, with a 0% mortality in simple cases and 10.6% mortality in moderate/complex cases (6). The highest mortality in this series was represented, not surprisingly, by patients with a Fontan type circulation. Standard severity of illness scoring systems did not accurately predict mortality in this study but abnormal pre-operative thyroid function, creatinine and bilirubin were highly predictive of mortality.

References

1. Warnes CA. The Adult with Congenital Heart Disease: Born to Be Bad? *Journal of the American College of Cardiology* 2005; 46 (1): 1-8
2. Shinebourne EA, Babu-Narayan SV, Carvalho JS. Tetralogy of Fallot: from Fetus to Adult. *Heart* 2006; 92: 1353-1359
3. ACC/AHA 2008 Guidelines for the Management of Adults with Congenital Heart Disease. *Journal of the American College of Cardiology* 2008; 52 (23): e143-263
4. Taylor JFN. Investigations before reoperations in congenital heart disease. In: Stark J, Pacifico AD (Eds.) *Reoperations in Cardiac Surgery* (Ch 1, pp. 3-16). Springer-Verlag, 1989
5. Lovell AT. Anaesthetic implications of grown-up congenital heart disease. *British Journal of Anaesthesia* 2004; 93 (1): 129-139
6. Price S, Jaggari SI, Jordan S et al. Adult congenital heart disease: intensive care management and outcome prediction. *Intensive Care Med* 2007; 33: 652-659

Percutaneous valve implantation – The anaesthesiologist's point of view

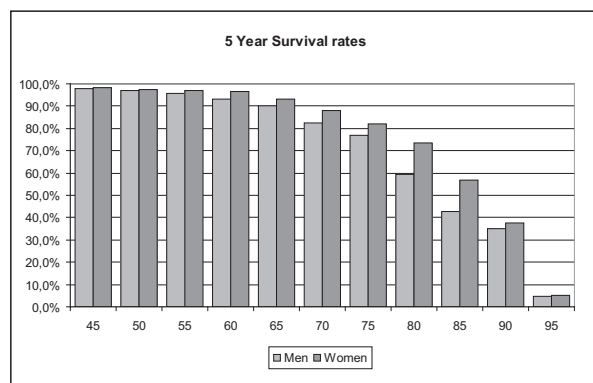
C.-J. Jakobsen

Aarhus University Hospital – Skejby, Aarhus, Denmark

Cather based aortic valve replacement is very different from standard cardiac surgery. The pain issue is not existing for transfemoral, while both per- and postoperative pain might be seen in the transapical approach. Consequently sedation is normally adequate during most of the procedure and the needs for analgesics are relatively low. However, due to the use of peroperative transoesophageal echocardiography and the, although short periods of pacing and ballooning, we have chosen a general anaesthesia – a modus we refer to as “anaesthesia light”.

At present the procedure is still in the experimental phase and thus the patients are mostly patients, which are inoperable due to surgical problems like glass aorta or due to high co-morbidity. At present we are conducting a study randomizing patients to either standard procedure or the transapical procedure.

One major issue in the implementation phase has been the age and co-morbidity of selected patients. Above all, age beyond 85 years has been an issue, especially taking the cost of the procedure into consideration. These facts might impose psychological depended reluctance to follow the increased demand for cardiac surgery in the elderly population. However, looking on facts of life expectance the 5 year life expectancy of an 80 year old woman is not much different from a 75 year old man and we need to look at late 80th or early 90th before the 5 year “survival” rate of the normal population is less than 50%.



Teambuilding

Both transfemoral and transapical valve replacement is a complex procedure involving cardiologists, surgeons and anaesthesiologists. It is important that all involved are equally part of the team. Good communication procedures (agreed communication guidelines) are essential. It should be clear, who is the leader of the team and also it should be agreed and respected, when a hold or a veto is expressed from other participants (both before and during the procedure). This aspect might seem trivial but nevertheless has been proven important in carrying out the procedures successfully.

Preoperative evaluation

From the anaesthetist point of view the patient's comorbidity and any impact on the procedure are essential. Significantly decreased pulmonary function is a major issue and it should be established beyond reasonable doubt that any problem is not primarily related to a pulmonary problem and that a decreased "pulmonary function" can be helped by a new valve. The accepted lower values of pulmonary function are in apical procedures a FEV₁ being 40% of predicted, while in femoral procedures we accept 30% of predicted FEV₁. The essential is: How **to know** when to say **NO**.

Primary concerns

The primary concerns of perioperative complications from anaesthetist point of view are compromised cardiac function due to catheters/guide wires in small valve lumen, afterload collapse, arrhythmias and aortic tear or rupture resulting in severe bleeding.

Main focus

The anaesthetists' main focus areas are the need for perioperative transoesophageal echocardiography, the short periods of ballooning with consequently no or little circulation and that the patients often have an extreme low aortic valve area (0.5cm² or lower). Postoperative pain relief may be an issue, especially after the apical approach, but due to anticoagulation therapy we have denounced the use of epidural analgesia. The primary focus during anaesthesia is the often severely reduced pulmonary function and our experience has shown that keeping afterload is one of the mandatory goals. Thus overall the Anaesthetic protocol is based on sedation with extubation in the OR, low dose analgesics, primary use of local anaesthetics and haemodynamic control guided by invasive monitoring.

Perioperative

There might be principal "differences" between the cardiologists and anaesthetists approach to the control of the circulation. Cardiologists focus on structural contractility, pressure and heart rate while the anaesthetists often focus on flow.

Monitoring

How intensive and why important? During the procedure the blood pressure and heart rate may slowly decrease, TEE might show unchanged or indeed slightly better contractility, however cardiac output may very well decrease rather much. Normal haemodynamic values in 80 and 90 year old people are substantially lower than younger patients and the actual possibilities of compensation of changes are rather different from normal cardiac patients. Cardiac index of 1.2 to 1.4 and SvO₂ in the range of 40-50 is often seen preoperatively in our patients older than 85 years with severe aortic stenosis. Thus all patients are monitored with invasive arterial pressure and pulmonary artery catheter (PAC) together with a CVC for medications. All lines are placed before anaesthesia using local analgesics.

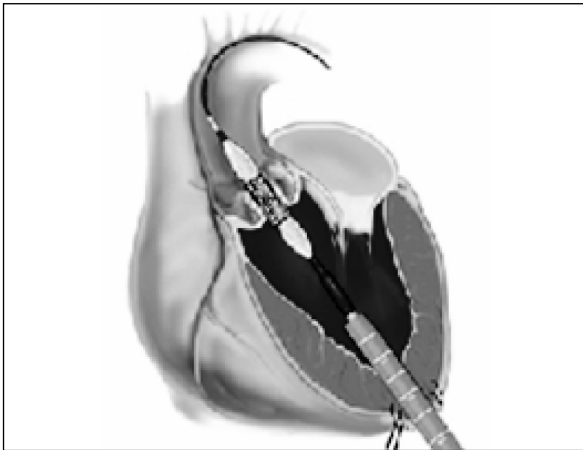
Haemodynamic variables (in cardiac surgical patients*)		
	60 Yr	80 Yr
Cardiac index (L/min/m ²)	2.7-3.2	1.7-2.4
SvO ₂ (%)	60-75	50-60
Saturation (%)	97-99	93-98

*) Preoperative "normal" values

Anaesthetic drugs – is the choice important?

Most anaesthetics have a negative impact on haemodynamic variables as CI and blood pressure. Keeping blood pressure is essential, one of primary reasons that full monitoring is to established before induction. Our normal routine is establish infusion line and keep open with noradrenalin 0.01µg/kg/minute, followed by induction with S-Ketamin 0.5 mg/kg, Sufentanil 15-25 µg and Rocuronium for intubation. Maintenance of anaesthesia is Sevoflurane 1-1.5 % with special attention to afterload. Thus we intend to keep blood pressure within 20 % of starting values with balanced use of Sevoflurane and noradrenaline.

Heart rate might be a problem and although a pacemaker is placed early in procedure it often does not help, as this is only ventricular pacing which use often will result in decreased circulation as many patients due to low general cardiac function are dependent of synchronic two chamber function.



Keeping ahead of the procedure

60-90 seconds before expected stop in circulation (pacing test, ballooning and valve placement) a bolus dose of noradrenalin (0.02 µg). The main problem in this phase is bleeding from the sheath (especially the apical procedure) if procedure time is long and the compromised haemodynamics during valve placement as delivery system may fill the whole lumen more or less.

Postoperative

All patients are extubated in the OR and we have established a procedure with very early mobilisation.

Pain control

The femoral approach is not followed by noteworthy postoperative pain. However the apical approach is most often followed by moderate pain, which is controlled by Bupivacain infiltration of the thoracic incision and 20 ml Bupivacain (5 mg/ml) into the pleura. If needed small doses of morphine or Fentanyl postoperatively. In continued pain, Ketoralac has proven effective for drain pain and if not sufficient we used intercostal blocks. Drains are normally removed after 4-6 hours.

Patients are observed until next morning in cardiac recovery unit. However more than half the patients is eligible for discharge relatively soon after the procedure. Different from standard surgery late problems might be increased s-creatinine on day 2-4 especially in even moderately impaired preoperative kidney function and procedures with preoperative increased use of contrast.

Neurologic complications after cardiac surgery

B. Jungwirth

Klinik für Anaesthesiologie, Klinikum rechts der Isar der Technischen Universität München, Germany

Neurologic deficits after cardiac surgery persist as common complications. Clinical manifestations of these deficits are variable, ranging from frank stroke as worst case scenario (incidence of 1 – 5%) to the more subtle neurocognitive deficits (incidence up to 80%) (1,2). The etiology leading to neurologic injury is most likely multifactorial with cerebral emboli (solid or gaseous), cerebral hypoperfusion, reperfusion injury and inflammatory reaction as main contributors (3). Risk factors for neurologic injury include but are not restricted to age, poor preoperative cognitive state, presence of cerebrovascular disease, atheromatous disease of the aorta. Women appear to be at higher risk for stroke after cardiac surgery than men (4).

Several studies have assessed the effect of both pharmacological and non-pharmacological strategies to prevent or minimize neurologic deficits following cardiac surgery. Despite promising preclinical data assessing potential neuroprotective drugs clinical trials showed conflicting results so that currently no drug can be recommended as neuroprotectant during cardiac surgery. However, ongoing studies investigating N-methyl-D-aspartate (NMDA) antagonists or anti-inflammatory agents in the setting of cardiac surgery might allow a reduction in the incidence of adverse neurologic outcomes.

With regard to non-pharmacological neuroprotective strategies, it seems to be essential to avoid the generation of solid cerebral emboli during cardiac surgery by minimizing aortic manipulation using only a single clamp application or optimizing cannulation and clamp placement using epi-aortic scanning (5). Cerebral air emboli as another contributing factor to adverse cerebral outcome after cardiac surgery should be avoided by optimizing de-airing after open heart surgery or by avoiding augmented venous return with a higher risk of air-entrainment in the CPB circuit. Surprisingly, studies comparing off-pump with on-pump coronary artery bypass surgery have shown comparable results in younger patients (6). Temperature, intra- and postoperative, seems to play an important role, as both faster rewarming rate as well as postoperative hyperthermia led to adverse cerebral outcomes (7). The

optimal haematocrit and the optimal blood pressure during and after cardiac surgery are not known yet.

References

1. Roach G. *N Engl J Med* 1996; 335: 1857-63
2. Newman MF. *N Engl J Med* 2001; 344: 395-402
3. Pugsley W. *Stroke* 1994; 25: 1393-9
4. Hogue CW. *Ann Thorac Surg* 2003; 76: 1119-25
5. Hammon JW. *J Thorac Cardiovasc Surg* 2006; 131: 114-21
6. van Dijk D. *JAMA* 2007; 297: 701-8
7. Grocott HP. *Stroke* 2002; 33: 537-41

Surgery in deep hypothermic circulatory arrest: Still much to study

K. Kiviluoma

Professor of Anesthesiology and Intensive Care, Department of Anesthesiology Oulu University and Oulu University Hospital, Oulu, Finland

Surgical repair of aortic arch aneurysms and dissections or complicated congenital heart anomalies often require bloodless operation field. Sometimes blood flow must be interrupted to make operation possible. The brain is the most sensitive organ to ischemia, and consequently neurological complications are the leading cause of mortality and especially morbidity in settings requiring circulatory arrest. Hypothermia has been used about 50 years to protect tissues and organs from the damage caused by ischemia. Hypothermic circulatory arrest (HCA) has been a standard for these operations, although new strategies like selective cerebral perfusion or retrograde perfusion have been introduced.

Ischemic damage occurs in two steps. First and crucial damage occurs during the ischemia due to lack of oxygen. High energy phosphates are depleted and active ion transport is inhibited. Cell membranes depolarize, intracellular calcium increases and lactate accumulates. Excitatory neurotransmitters like glutamate accumulate in synapses. If long enough ischemia can lead to necrosis. The second step of damage occurs during reperfusion. Activation of complement, activated leucocytes and pro-inflammatory cytokines cause inflammation, which worsens the situation more.

Cerebral metabolic rate is dependent of temperature being about 50 % of normal at 30°C temperature, 25 % at 20°C and 12% at 10°C. Corresponding limits for tolerable ischemia being 5 minutes at 37°C, 9 min at 30°C, 21 min at 20°C and 45 min at 10°C. Some kind

of selective perfusion is thought to prevent brain from damage caused by ischemia. These innovations have gone to clinical use mostly with little experimental data.

To get deeper knowledge of HCA and brain protection we have over carried out decade studies with our chronic porcine model first developed in Mount Sinai Hospital. The basic protocol is to cool pigs to 18°C, have 75 min HCA and follow pigs one week after the experiment. A lot of data is collected during experiments.

We started by studying retrograde cerebral perfusion, which was a hot topic during that time. It seems that the benefit of retrograde perfusion of head is mainly due to improved brain cooling. Later we have concentrated more to study possible medications and perfusion strategies that could minimize the injury. Overall pH-stat management during hypothermia seems to be safer than alpha-stat management. Anti-epileptic drug lamotrigine might have some positive effects. Nutritive support by fructose-1,6-bisphosphate has some beneficial effects. Anti-inflammatory managements like leukocyte-filtration or hypertonic saline have beneficial neuroprotective effect. Leukocyte-filtration succeeds to reduce the number of adherent leukocytes seen in intravital microscopy during reperfusion. Remote ischemic preconditioning has been shown to increase ischemic tolerance in many organs. In our new series remote ischemic preconditioning protected brain against HCA-induced injury.

Based on our experience mechanisms of HCA induced injury and possible protective methods still need active research. In clinical work every new technique for complicated procedures should be compared to HCA.

Perioperative anemia

A. Maniatis

A significant percentage of patients presenting for surgical procedures are anaemic, as defined by WHO criteria (Hb<12g/dl for women, <13g/dl for men). Preoperative screening is often carried out after surgery has been scheduled and surgeons and anaesthetists resort to transfusion so as to correct anaemia and avoid delays of surgeries.

Transfusion may have immediate benefit but its effect is short-lived, it carries numerous risks, it has significant cost and availability may be a problem.

To the known transfusion risks and reactions – disease transmission, postoperative infections, TRALI – recent studies suggest yet another one, namely increased postoperative morbidity and mortality, after cardiac surgery, related to changes occurring in stored blood (1).

Data on perioperative transfusions documented in a number of studies are showing large practice variations that can not be easily justified. In cardiac surgery transfusion rates are high ranging from 11-97% (2). In fact in England it has been estimated that 10-15% of units issued by the National Blood Service are used in cardiac surgery; the percentage in the USA is even higher 20%!

Efforts at avoiding transfusion of allogeneic blood, initially centered on autologous blood (by Predonation, Acute Normovolemic Hemodilution or Cell Salvage intra- or postoperatively) and these modalities are still used to varying degrees.

More recent studies identified preoperative anaemia as one of the risk factors for perioperative transfusions and have included it in algorithms and scoring systems such as the TRUST and TRACK score systems. These systems include other risk factors such as age, sex, weight and surgical complexity and have a significant predictive value for transfusion planning (3).

Adopting however guidelines and complex algorithms has proven difficult. I would therefore like to propose that progress could be made by focusing on at least one risk factor which may be easy to correct, namely preoperative anaemia. In a recent study anaemia was documented as an independent predictor of perioperative outcome, in patients scheduled for elective vascular surgery (4).

Perioperative anaemia may be the result of true iron deficiency in 30% of cases, or to functional iron deficiency in another 30%, in the setting of chronic disease prevalent in the older population; smaller percentages may be due to B12 or Folate deficiencies.

Erythropoietin for anaemia correction was shown to be effective in decreasing exposure to transfusion in both orthopedic and cardiac surgery patients already 10 years ago, in the SPOT study (5). More recently Alghamdi et al showed in a meta-analysis that the administration of erythropoietin prior to cardiac surgery resulted in reduction in the risk of exposure to allogeneic blood transfusion (RR=0.53, p<0.01) (6).

In their clinical practice guideline, on perioperative blood transfusion and blood conservation, cardiovascular surgeons and anaesthesiologists have included the use of erythropoietin to increase RBC mass preop-

eratively (7). However recent concerns with regard to possible untoward effects of erythropoiesis stimulating agents have led to caution in their use.

Erythropoietin should only be used if nutritional deficiencies have been ruled out and iron availability is a prerequisite for its effectiveness. The use of iron especially in its intravenous form has recently been introduced for the treatment of heart failure and ongoing studies will clarify its impact on anaemia correction in this setting (IRON-HF study) (8); meantime intravenous iron is being used in preoperative anaemia correction in a number of surgeries including cardiovascular. In a recently published study on the development of a preoperative blood saving protocol for orthopedic surgery, intravenous iron was recommended for patients with Hb \geq 13g/dl and ferritin $<$ 50 μ g/l or intolerance to oral iron. Patients with Hb between 10-13g/dl received EPO + iv iron. This intervention led to a decrease in transfused patients from 31.5 to 18.8% (9).

There are now several iron preparations licensed for intravenous use with an excellent safety profile that can be used in short infusion schedules or even directly i.v.

In order to effectively treat preoperative anaemia, patients should ideally be screened 30 days before surgery which represents the main stumbling block in adopting this strategy! There is evidence however that by combining EPO with intravenous iron one can improve anaemia in only two weeks.

There is no doubt that in order to make a serious impact on blood conservation in surgery, one needs a multimodality approach such as has been described in a number of protocols (10). One can only hope that more surgical teams will adopt protocols appropriate for their patients, thus contributing to blood conservation. But whereas many of the proposed interventions apply to certain patient categories only, correction of preoperative anaemia is necessary for all elective surgical patients and implementing anaemia management will improve their outcomes.

References

1. Koch CG, Li L, Sessler DI et al. Duration of red-cell storage and complications after cardiac surgery. *N Engl J Med* 2008; 358: 1229-1239
2. Shehata N, Naglie G, Alghamdi AA et al. Risk factors for red cell transfusion in adults undergoing coronary artery bypass surgery: a systematic review. *Vox Sang* 2007; 93: 1-11
3. Ranucci M, Castelvechio S, Frigiola A et al. Predicting transfusions in cardiac surgery: the easier, the better: the Transfusion Risk and Clinical Knowledge score. *Vox Sang* 2009; 96: 324-332

4. Dunkelgrun M, Hoeks SE, Welten GM et al. Anaemia as an independent predictor of perioperative and long-term cardiovascular outcome in patients scheduled for elective cardiovascular surgery. *Am J Cardiol* 2008; 101: 1196-200
5. Laupacis A, Fergusson D. Erythropoietin to minimize perioperative transfusion: a systematic review of randomized trials. The international Study of Perioperative Transfusion (SPOT) Investigators. *Transfusion Medicine* 1998; 8: 309-17
6. Alghamdi AA, Albanna MJ, Guru V, Brister SJ. Does the use of erythropoietin reduce the risk of exposure to allogeneic blood transfusion in cardiac surgery? A systematic review and meta-analysis. *J Card Surg* 2006; 21: 320-6
7. The Society of Thoracic Surgeons Blood Conservation Guideline Task Force; The Society of Cardiovascular Anaesthesiologists Special Task Force. Perioperative blood transfusion and blood conservation in cardiac surgery: the society of thoracic surgeons and the society of cardiovascular anaesthesiologists clinical practice guideline. *Ann Thorac Surg* 2007; 83: S27-86
8. Beck-da-Silva L, Rohde LE, Pereira-Barretto AC et al. Rationale and design of the IRON-HF study: a randomized trial to assess the effects of iron supplementation in heart failure patients with anaemia. *J Card Fail* 2007; 13: 14-7
9. Gonzales-Porras JR, Colado E, Conde MP et al. An individualized pre-operative blood saving protocol can increase pre-operative haemoglobin levels and reduce the need for transfusion in elective total hip or knee arthroplasty. *Transfusion Medicine* 2009; 19: 35-42
10. Van der Linden P, Dierick A. Blood conservation strategies in cardiac surgery. *Vox Sang* 2007; 92: 103-112

Can we reduce the risks of the high-risk cardiac surgery patient?

W. T. McBride

Department of Cardiac Anaesthesia, Royal Victoria Hospital, Belfast, Northern Ireland, UK

Introduction

In this review some recent developments and controversies in perioperative strategies to improve outcomes following cardiac surgery will be discussed.

Reducing ventilation time following cardiac surgery

Patients with impaired lung function tests are at increased risk of prolonged ventilation after cardiac surgery.

Of 388 patients intended for fast track extubation following cardiac surgery the most common reasons for delayed extubation included deep sedation (46.5%), confusion 44 (25%), excessive bleeding in 20 (11.3%) and high inotropic support in 10 (5.68%) [1]. Many of these issues can be addressed by modifications in

anaesthetic technique and are particularly relevant in patients with impaired lung function preoperatively.

Various non-invasive methods are available to assist ventilation in extubated cardiac surgery patients. These include positive pressure ventilation methods by the continuous positive airway pressure (CPAP) hood or face mask or negative pressure ventilation by external cuirass negative pressure ventilation [2]. The latter has the advantage of haemodynamic improvement following cardiac surgery [3].

The minimized extracorporeal circulation system (MECC) reduces priming volumes and blood-foreign surface interaction. Although an improvement in post-operative FEV1 was found in comparison with conventional circuits there was no significant reduction in ventilation times [4]. This technique awaits fuller evaluation to establish improved lung function outcomes [5].

Influencing outcomes in patients with preoperative renal failure

Traditional ideas that preoperative renal dysfunction heightens risk of postoperative dialysis dependent renal failure have been recently questioned in light of the finding that patients with chronic renal dysfunction have developed anti-inflammatory strategies to minimize the perioperative inflammatory response which theoretically allows such patients to successfully undergo surgery with acceptable risks [6]. This theoretical postulation has been supported by 2 recent studies. Chirumamilla et al. used perioperative changes in MDRD (Modification of Diet in Renal Disease) estimated glomerular filtration rate (GFR) to follow outcomes in 1055 coronary artery bypass graft surgery (CABG) patients who were categorized according to their preoperative renal function into 4 GFR groups (normal GFR, and mild, moderate and severe GFR impairment). Patients presenting with preoperative renal insufficiency had particular care taken to avoid perioperative hypotension, fluid overload, excessive cardioplegia and excessively long CPB times through performing only essential grafts. Interestingly there were no statistically significant outcome differences between the preoperative GFR groups [7]. Arguably the special measures taken by Chirumamilla should apply to all patients irrespective of preoperative renal status. Similarly it was shown that in the 25-year period between 1977 and 2002, 255 (2.6%) of 9721 valve surgery patients developed dialysis dependent renal failure. Surprisingly preoperative renal dysfunction was not identified as a predisposing factor to renal dys-

function in valve surgery [8]. However, positive predictors of mortality post operatively were emergent status, ischemic and surgical times, surgical hemorrhage, and nosocomial infection/preoperative endocarditis [8].

Modulating the inflammatory response

It is accepted that the kidneys are vulnerable to a perioperative inflammatory response [9, 10]. Since a significant part of the inflammatory response arises from the interaction of the blood with the foreign surface of the cardiopulmonary bypass machine there has been much interest if the OFF PUMP technique is associated with better renal outcomes than ON PUMP. In a study of 50 patients randomized to ON PUMP or OFF PUMP Ascione suggested that OFF PUMP surgery had less renal dysfunction than on pump surgery [11] possibly as a result of less pronounced inflammatory response. This finding has not been universally supported. For example, although biological markers of inflammation are less marked in OFF PUMP compared with ON PUMP patients in a study of 100 patients randomized to OFF PUMP or ON PUMP CABG, it was found that SVR values were comparable between the groups with 42% of OPCAB and 32% of ONCAB patients developing a very low SVR index ($<1,500 \text{ dyne} \times \text{cm}^{-5} \times \text{m}^{-2}$) ($P > 0.05$). There were no between group outcome differences with excellent cardiac outputs and clinical outcomes in both groups [12].

Do commonly administered drugs in the intensive care unit influence renal outcomes?

Dopamine, dopexamine, frusemide

In a study of 126 elective cardiac surgery patients randomized to receive infusions of dopamine (Renal dose) frusemide or normal saline (placebo) it was found that dopamine did not improve outcome (as measured by differences in Delta (MAX) creatinine, whereas frusemide may even worsen outcomes after cardiac surgery [13]. Low dose dopexamine did not alter renal function compared with placebo [14].

Reducing surgical haemorrhage postoperatively

For many years intravenous aprotinin has been used to reduce postoperative bleeding but has been withdrawn from the market due to excessive complications. Contrasting studies on this issue have recently emerged. In support of the unsuitability of aprotinin in cardiac surgery is the meta-analysis by Henry of 49 trials involv-

ing 182 deaths among 7439 patients where the risk of death tended to be consistently higher with use of aprotinin than with use of tranexamic acid and epsilon amino caproic acid. The authors concluded that since aprotinin had no clear advantages to offset these harms that either tranexamic acid or epsilon aminocaproic acid should be recommended to prevent bleeding after cardiac surgery [15].

In a contrasting study of 298 normal renal function heart surgery patients scheduled for low- or intermediate-risk procedures and randomised to receive either tranexamic acid, high-dose aprotinin, or placebo it was found that aprotinin was about twice as effective as tranexamic acid in reducing total postoperative blood loss. Unlike tranexamic acid, aprotinin completely abolished bleeding-related re-explorations. Of note, aprotinin did not significantly increase mortality compared with tranexamic acid or placebo. The authors concluded that aprotinin had advantages over tranexamic acid provided it is restricted to low or intermediate risk cardiac surgery [16].

Recently topical use of the antifibrinolytics, aprotinin or tranexamic acid into the pericardium has been found to significantly reduce bleeding postoperatively [17].

Recently the use of the minimized extracorporeal circulation system (MECC) has been associated with reduced need for blood transfusion [4].

However as with all areas of outcome modification it is unlikely that one “magic bullet” will achieve the goal of reduced adverse outcomes but rather a combination of management strategies. This has been highlighted by Ranucci who suggested that postoperative bleeding can be satisfactorily reduced by a combination approach of (a) routine use of tranexamic acid, (b) heparin dose-response monitoring, thromboelastography, platelet (PLT) function analysis in a select population of patients, and (c) use of fresh frozen plasma (FFP), platelets, and desmopressin according to the hemostasis [18].

Reducing cognitive dysfunction after heart surgery

In a study of cardiac surgery involving cardiopulmonary bypass using closed cardiopulmonary bypass circuits and controlled suctions of pericardial shed blood, 30 patients were randomized to either standard noncoated or heparin-coated extracorporeal circuits. Complement activation and glial injury as estimated by s100beta measurement was reduced in the heparin coated group compared with the standard group. How-

ever there were no statistically significant between group differences in cognitive testing [19]. Cerebral regional oxygen saturation (rSO₂) measured using Near Infra Red Spectroscopy (NIRS) is now widely used. It has been shown that rSO₂ correlates with superior vena cava saturation (ScvO₂) continuously measured with a Peditasat catheter in paediatric heart surgery patients [20]. By seeking to maintain rSO₂ above desaturation threshold cognitive dysfunction postoperatively may be reduced [21]. Rubio et al in aortic arch surgery showed that during low-flow antegrade perfusion via the innominate artery, a reduction in rSO₂ below the desaturation threshold correlated with displacement of incorrect positioning of the arterial cannula in the right subclavian artery [22].

Reducing gut ischemia at cardiac surgery

Clinical use of gastric tonometry

By simultaneous measurement of gastric pCO₂ using gastric tonometry (PgCO₂) and either arterial pCO₂ (paCO₂) or end tidal pCO₂ (etCO₂) the CO₂ gap can be calculated [P(g-a)CO₂ or P(g-et)CO₂]. It has been proposed that this value can be proposed to direct therapy as soon as its value goes beyond 12 to 15 mmHg. If an empirical therapeutic decision (fluid challenge, low dose inotrope) is not followed by improvement, the central hemodynamics need to be re-assessed and corrected as necessary. Kaplan Meir curves show that CO₂ gap predicts outcomes in critically ill patients [23].

By referencing pgCO₂ to paCO₂ (Pg-aCO₂), this measurement has proved to be an early indicator of shock and a good predictor of postoperative complications [24] in cardiac surgery. Lebuffe et al. found that a high Pg-etCO₂ on admission to the ICU as well as high Pg-aCO₂ were associated with a poorer outcome following cardiac surgery [25]. Hence, semi-continuous monitoring of Pg-etCO₂ might allow earlier intraoperative prediction of poor outcome at a time when intervention may be helpful.

Laser doppler flowmetry

1. This instrument is used to assess jejunal mucosal perfusion and jejunal mucosal haematocrit and red blood cell velocity. It involves passing a probe under endoscopic control into the jejunum. The instrument called the PeriFlux System 5000 enables the simultaneous measurement of (laser Doppler) jejunal mucosal perfusion (JMP) and jejunal transcutaneous pO₂/CO₂ [26]. The method is really an experimental tool at

present as routine endoscopy is impractical. Nevertheless interesting results have emerged from recent studies. Jejunal mucosal autoregulation was shown with this technique during various flow states at cardiopulmonary bypass, a protective mechanism hitherto unknown at cardiac surgery and which is removed in the presence of prostacyclin infusion [26].

Future developments

Polymorphisms

Can polymorphisms influence renal function postoperatively?

Apolipoprotein E (APO-E)

Chew and Newman performed a prospective observational study with use of data from 564 coronary bypass surgical patients who were enrolled in an ongoing investigation of apolipoprotein E genotypes and organ dysfunction between 1989-1999. Renal function was assessed among apolipoprotein E genotype groups by comparisons of preoperative (CrPre), peak in-hospital postoperative (CrMax) and perioperative change (DCr) in serum creatinine values. They found that the epsilon4 allele grouping (E2 = 2/2,2/3,2/4; E3 = 3/3; E4 = 3/4,4/4) was associated with a smaller increase in postoperative serum creatinine (perioperative change: E2, +0.17; E3, +0.26; E4, +0.27 mg/dl) and a lower peak postoperative creatinine than the epsilon2 and epsilon3 in univariate and multivariate analysis. Inheritance of the apolipoprotein epsilon4 allele is associated with reduced postoperative increase in serum creatinine after cardiac surgery, compared with the epsilon3 or epsilon2 allele. The authors claimed that this was the first genetic basis for acute perioperative renal impairment [27].

More recently 1671 patients undergoing aortocoronary surgery were studied for genetic factors associated with postoperative acute renal injury. Because a race effect was found Caucasian and African Americans were analyzed separately. The following alleles were linked with renal dysfunction in Caucasians

- angiotensinogen 842C
- angiotensin receptor1 1166C, and
- interleukin 6 -572C and
- endothelial nitric oxide synthase [eNOS] 894T
- apo lipoprotein-E 448C

In African Americans

– eNOS 894T and

– **angiotensin-converting enzyme (ACE) deletion and insertion**

were associated with renal dysfunction post operative-ly [28].

Angiotensin converting enzyme and ACE gene polymorphisms

Stafford-Smith et al highlighted the possibility of genes of the RAAs system being involved in **acute** renal dysfunction. Until this time however, these genes were more commonly associated with **chronic** renal dysfunction. If this is found to be significant ACE inhibitor drugs and angiotensin II receptor blockers may be implicated in perioperative renal dysfunction.

Anti-endotoxin core antibodies

In a study of 301 patients undergoing coronary artery bypass graft surgery and/or valvular heart surgery lower preoperative serum antiendotoxin core antibody (IgM EndoCab) level independently predicted ($P=0.002$) adverse outcome defined as either in-hospital death or postoperative length of stay greater than 10 days [29]. A clinical application of this finding such as antiendotoxin core vaccine preoperatively is awaited.

Conclusion

It is unlikely that a “magic bullet” will be found to single handedly improve outcomes in the high risk cardiac surgery patient. A combination of early detection of patients at high risk and meticulous attention to protecting all organ systems through optimizing surgical, perfusion, pharmacological and ventilation techniques is needed to allow higher risk patients to safely undergo cardiac surgery.

References

- Akhtar MI, Hamid M. Success and failure of fast track extubation in cardiac surgery patients of tertiary care hospital: one year audit. *J Pak Med Assoc* 2009; 59: 154-56
- Trethowan B, Elliott P, Varadarajan B, McBride WT. Continuous negative extra thoracic pressure in respiratory complications after cardiac surgery. *Br J Anaesth* 101: 589P-90P
- Chaturvedi RK, Zidulka AA, Goldberg P, deVarennes B, Iqbal S, Rahme E et al. Use of negative extrathoracic pressure to improve hemodynamics after cardiac surgery. *Ann Thorac Surg* 2008; 85: 1355-60
- Kofidis T, Baraki H, Singh H, Kamiya H, Winterhalter M, Didilis V et al. The minimized extracorporeal circulation system causes less inflammation and organ damage. *Perfusion* 2008; 23: 147-51
- Ti LK, Goh BL, Wong PS, Ong P, Goh SG, Lee CN. Comparison of mini-cardiopulmonary bypass system with air-purge device to conventional bypass system. *Ann Thorac Surg* 2008; 85: 994-1000
- Baker RC, Armstrong MA, Allen SJ, McBride WT. Role of the kidney in perioperative inflammatory responses. *Br J Anaesth* 2002; 88: 330-34
- Chirumamilla AP, Wilson MF, Wilding GE, Chandrasekhar R, Ashraf H. Outcome of Renal Insufficiency Patients Undergoing Coronary Artery Bypass Graft Surgery. *Cardiology* 2008; 111: 23-29
- Chan V, Jamieson WR, Chan F, Germann E. Valve replacement surgery complicated by acute renal failure – predictors of early mortality. *J Card Surg* 2006; 21: 139-43; discussion 144-5
- Gormley SM, McBride WT, Armstrong MA, Young IS, McClean E, MacGowan SW et al. Plasma and urinary cytokine homeostasis and renal dysfunction during cardiac surgery. *Anesthesiology* 2000; 93: 1210-6; discussion 5A
- Gormley SMC, McBride WT, Armstrong MA, Young IW, McClean E, MacGowan SW et al. Plasma and urinary cytokine homeostasis and renal function during cardiac surgery without cardiopulmonary bypass. *Cytokine* 2002; 17: 61-65
- Ascione R, Lloyd CT, Underwood MJ, Gomes WJ, Angelini GD. On-pump versus off-pump coronary revascularization: evaluation of renal function. *Ann Thorac Surg* 1999; 68: 493-98
- Tatoulis J, Rice S, Davis P, Goldblatt JC, Marasco S. Patterns of postoperative systemic vascular resistance in a randomized trial of conventional on-pump versus off-pump coronary artery bypass graft surgery. *Ann Thorac Surg* 2006; 82: 1436-44
- Lassnigg A, Donner E, Grubhofer G, Presterl E, Druml W, Hiesmayr M. Lack of renoprotective effects of dopamine and furosemide during cardiac surgery. *J Am Soc Nephrol* 2000; 11: 97-104
- Allen SJ, Penugonda SP, Baker RC, Young I, McMurray TJ, Armstrong MA et al. Low dose dopexamine does not alter sub-clinical renal indices following cardiac surgery. *European J of Anaesthesiology* 2003; 20: 12
- Henry D, Carless P, Fergusson D, Laupacis A. The safety of aprotinin and lysine-derived antifibrinolytic drugs in cardiac surgery: a meta-analysis. *CMAJ* 2009; 180: 183-93
- Later AF, Maas JJ, Engbers FH, Versteegh MI, Bruggemans EF, Dion RA et al. Tranexamic acid and aprotinin in low- and intermediate-risk cardiac surgery: a non-sponsored, double-blind, randomised, placebo-controlled trial. *Eur J Cardiothorac Surg* 2009
- Abrishami A, Chung F, Wong J. Topical application of antifibrinolytic drugs for on-pump cardiac surgery: a systematic review and meta-analysis. *Can J Anaesth* 2009; 56: 202-12
- Ranucci M, Castelvechio S, Romitti F, Isgro G, Ballotta A, Conti D. Living without aprotinin: the results of a 5-year blood saving program in cardiac surgery. *Acta Anaesthesiol Scand* 2009
- Baufreton C, Allain P, Chevailler A, Etcharry-Bouyx F, Corbeau JJ, Legall D et al. Brain injury and neuropsychological outcome after coronary artery surgery are affected by complement activation. *Ann Thorac Surg* 2005; 79: 1597-605
- Ranucci M, Isgro G, De la Torre T, Romitti F, Conti D, Carlucci C. Near-infrared spectroscopy correlates with continuous superior vena cava oxygen saturation in pediatric cardiac surgery patients. *Paediatr Anaesth* 2008; 18: 1163-69

21. Kane JM, Steinhorn DM. Lack of irrefutable validation does not negate clinical utility of near-infrared spectroscopy monitoring: Learning to trust new technology. *J Crit Care* 2008
22. Rubio A, Hakami L, Munch F, Tandler R, Harig F, Weyand M. Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the aortic arch surgery. *J Card Surg* 2008; 23: 474-79
23. Levy B, Gawalkiewicz P, Vallet B, Briancon S, Nace L, Bollaert PE. Gastric capnometry with air-automated tonometry predicts outcome in critically ill patients. *Crit Care Med* 2003; 31: 474-80
24. Bennett-Guerrero E, Panah MH, Bodian CA, Methikalam BJ, Alfaron JR, DePerio M et al. Automated detection of gastric luminal partial pressure of carbon dioxide during cardiovascular surgery using the Tonocap. *Anesthesiology* 2000; 92: 38-45
25. Lebuffe G, Decoene C, Pol A, Prat A, Vallet B. Regional capnometry with air-automated tonometry detects circulatory failure earlier than conventional hemodynamics after cardiac surgery. *Anesth Analg* 1999; 89: 1084-90
26. Nygren A, Thoren A, Houltz E, Ricksten SE. Autoregulation of human jejunal mucosal perfusion during cardiopulmonary bypass. *Anesth Analg* 2006; 102: 1617-22
27. Chew ST, Newman MF, White WD, Conlon PJ, Saunders AM, Strittmatter WJ et al. Preliminary report on the association of apolipoprotein E polymorphisms, with postoperative peak serum creatinine concentrations in cardiac surgical patients. *Anesthesiology* 2000; 93: 325-31
28. Stafford-Smith M, Podgoreanu M, Swaminathan M, Phillips-Bute B, Mathew JP, Hauser EH et al. Association of genetic polymorphisms with risk of renal injury after coronary bypass graft surgery. *Am J Kidney Dis* 2005; 45: 519-30
29. Bennett-Guerrero E, Ayuso L, Hamilton-Davies C, White WD, Barclay GR, Smith PK et al. Relationship of preoperative antiendotoxin core antibodies and adverse outcomes following cardiac surgery. *Jama* 1997; 277: 646-50

Managing material dependent and independent causes of the inflammatory response during cardiac surgery

W. T. McBride

Department of Cardiac Anaesthesia, Royal Victoria Hospital, Belfast, Northern Ireland, UK

For many years the perioperative inflammatory response has been linked with cardiopulmonary bypass and the interaction of blood with the foreign surface of the heart lung machine. The concept of biocompatible circuits was introduced in an attempt to minimize the magnitude of the perioperative inflammatory response. To some extent the use of heparin coating and other biocompatible surfaces was associated with reduced increases in perioperative inflammatory mediators [1,2] but not always [3]. However, the relative contribution of the cardiopulmonary (CPB) machine

to the overall perioperative inflammatory response was found to have been historically overestimated when the advent of OFF-PUMP cardiac surgery showed that in the absence of the CPB machine patients still sustained a significant perioperative plasma and urinary inflammatory response [4]. Moreover miniaturized extracorporeal circulation can be considered similar to off-pump surgery in terms of systemic inflammatory response, myocardial inflammation and damage, and early outcome [5]. In fact the disturbance to the clotting system caused by sternotomy and tissue damage may in itself trigger a proinflammatory response. This effect could be compounded by the retransfusion of unwashed mediastinal shed blood [6] or perioperative hypotension. The CPB machine only partially contributes to the overall inflammatory response. In vitro tests of biocompatible surfaces have suggested reductions in some proinflammatory mediators but not all [7]. Is there any point in pursuing and refining biocompatible technology? There are two reasons why the present author believes biocompatible CPB technology has made a significant contribution. Firstly, patients are increasingly treated preoperatively with Angiotensin Converting Enzyme (ACE) Inhibitors. Since the bradykinin increases in blood during CPB are controlled by the ACE enzyme, hypotension during CPB requiring vasoconstriction may result. It has been shown in patients on preoperative ACE inhibitor therapy that falls in blood pressure during CPB are less pronounced in patients undergoing CPB with biocompatible (SMART®) circuits than non-biocompatible circuits [8]. Avoiding peri-CPB hypotension has implication for overall organ protection including kidney and brain. Secondly, most patients are able to deal with the perioperative proinflammatory load. However, in patients in whom this load becomes overwhelming every precaution to minimise any bypass-based proinflammatory stimulus should be taken. This should include avoiding retransfusion of mediastinal shed blood which contributes significantly to the overall perioperative plasma and urinary inflammatory response [6].

References

1. Kutay V, Noyan T, Ozcan S, Melek Y, Ekim H, Yakut C. Biocompatibility of heparin-coated cardiopulmonary bypass circuits in coronary patients with left ventricular dysfunction is superior to PMEA-coated circuits. *J Card Surg* 2006; 21: 572-77
2. Lindholm L, Westerberg M, Bengtsson A, Ekroth R, Jensen, E, Jeppsson, A. A closed perfusion system with heparin coating and centrifugal pump improves cardiopulmonary bypass biocompati-

- bility in elderly patients. *Ann Thorac Surg* 2004; 78: 2131-8; discussion 2138
3. Defraigne JO, Pincemail J, Larbuissou R, Blaffart F, Limet R. Cytokine release and neutrophil activation are not prevented by heparin-coated circuits and aprotinin administration. *Ann Thorac Surg* 2000; 69: 1084-91
 4. Gormley SM, McBride WT, Armstrong MA, McClean E, MacGowan SW, Campalani G et al. Plasma and urinary cytokine homeostasis and renal function during cardiac surgery without cardiopulmonary bypass. *Cytokine* 2002; 17: 61-65
 5. Formica F, Broccolo F, Martino A, Sciuchetti J, Giordano V, Avalli L et al. Myocardial revascularization with miniaturized extracorporeal circulation versus off pump: Evaluation of systemic and myocardial inflammatory response in a prospective randomized study. *J Thorac Cardiovasc Surg* 2009; 137: 1206-12
 6. Allen SJ, McBride WT, McMurray TJ, Phillips AS, Penugonda SP, Campalani G et al. Cell salvage alters the systemic inflammatory response after off-pump coronary artery bypass grafting surgery. *Ann Thorac Surg* 2007; 83: 578-85
 7. Hoel TN, Thiara AS, Videm V, Fiane AE, Mollnes TE, Castellheim A et al. In vitro evaluation of PHISIO-coated sets for pediatric cardiac surgery. *Scand Cardiovasc J* 2009; 43: 129-35
 8. Allen S, McBride WT, Young IS, MacGowan SW, McMurray TJ, Prabhu S et al. A clinical, renal and immunological assessment of surface modifying additive treated (SMART) cardiopulmonary bypass circuits. *Perfusion* 2005; 20: 255-62

Life without aprotinin in pediatric cardiac surgery

P. Pouard, M. Bojan, S. Gioanni, P. R. Vouhé
Anesthesia, Pediatric Cardiac Intensive Care and CPB Unit, Departments of Anesthesiology, Intensive Care and Pediatric Cardiac Surgery, Necker Hospital for Sick Children, Paris, France

Aprotinin is a serine protease inhibitor that reduces bleeding through its antifibrinolytic and platelet protective properties. In pediatric cardiac surgery, when used at high dose regimen, it also reduces the inflammatory response to cardiac surgery. Because of the dreadful consequences of blood transfusion and enhanced inflammatory reaction during the neonatal period, it has been widely used since 1990. Many studies have demonstrated its efficacy even if a smaller number had not. There were always many difficulties to assess the efficacy of aprotinin because of the diversity of protocols, the different range of doses and the miscellaneous end points. In pediatric cardiac surgery few complications have been reported. The main complication is certainly the risk of anaphylactic reaction that can be easily controlled by giving aprotinin after the aortic cannulation in case of re-exposure. Neverthe-

less the risk of anaphylactic reaction at the first exposure albeit very rare, does exist. For pediatric cardiac anesthesiologists aprotinin has been a safe drug. In our institution, we have observed 2 severe anaphylactic reactions (without fatal outcome) for 11 000 patients. In a recent report, W Dietrich has reported a more frequent occurrence of the anaphylactic reaction in 12,403 exposures to aprotinin in cardiac surgery: 4.1%, 1.9%, and 0.4% in the less than 6 months, 6 to 12 months, and more than 12 months re-exposure intervals, respectively. Because of some controversial reports, that showed an increased risk of renal failure leading to dialysis, myocardial infarction, strokes and finally mortality rate in adult patients, aprotinin has been withdrawn between 2007 and 2008 depending on the countries.

More bleeding and consequently more RBC, FFP, and platelet transfusion as well as increased morbidity rate related with TRALI and inflammatory reaction would have been expected. Particularly in France where we have no alternative antifibrinolytics available: epsilon aminocaproic acid has been withdrawn years ago and tranexamic acid is contra-indicated in the neonates because of the risk of seizures.

Since the withdrawal of aprotinin (August 2008) we have studied the risk factors for platelet transfusion in 521 pts (299 with aprotinin, 222 without aprotinin):

	OR, IC95%	p
Risks factors for platelet transfusion :		
- Age <29 days	0.98[0.93, 1.04]	0.11
- CPB >120min	1.03[0.98, 1.08]	0.22
- Aristotle index >8	1.02[0.97, 1.07]	0.54
- Without Aprotinin	0.96[0.92, 0.99]	0.029
- Deep hypothermic circulatory arrest	1.18[1.08, 1.29]	0.0004
- Surgeon	1.01[0.98, 1.03]	0.67

There is a significant risk of platelet transfusion associated with a trend of increased transfusion of coagulation factors in the group without aprotinin.

To decrease the need of platelets and coagulation factors and overcome the lack of aprotinin:

1. We have modified the CPB circuits to decrease the dilutional effect of the priming volume. Our neonatal circuit can be primed with 125 ml (instead of 300 ml) and 110 ml after the connection of the tubing to the canulae. This includes the volume of warm blood cardioplegia directly bypassed from the main

circuit. In most of the cases CPB is performed at normothermia. Normothermia avoids the rewarming period, decreases vasodilation and reduces the need of filling volume. A small amount of ultrafiltration before the end of CPB allows to concentrate the coagulation factors and platelets. Early in pediatric cardiac surgery, F Kern showed that dilution at the onset of CPB was the main factor of coagulation disorders during the neonatal CPB. By reducing the dilution, it is now possible to use one RBC unit and one FFP unit for the procedure and the early post operative period if the residual blood of the CPB circuit is collected in a cell saver device.

2. We have also optimized anticoagulation by monitoring antithrombin (AT) level: in neonates, anticoagulation is more difficult to obtain, and more thrombin is produced responsible for more coagulation factors consumption and more inflammation. One of the reasons is the lowest level of AT, especially at the onset of CPB when a huge decrease of AT level occurs. By measuring preoperatively the AT level and using FFP to prime the pump, anticoagulation is more efficient and coagulation factors consumption and inflammation should be reduced.
3. We use tranexamic acid only in children older than 1 year old for reoperation, cyanosis with hemoglobin > 17g/dl and when the CPB is foreseen to last more than 2 hours.

Furthermore, it could probably be interesting to use vacuum-assisted venous drainage to increase the reduction of blood transfusion.

With these modifications, at the end of CPB there is no more need for platelets transfusion (platelet count is > 100 000/mm³) and coagulation factors are sufficient to avoid any additional coagulation factors transfusion. We have now to assess the role of this very small priming volume on the inflammatory reaction.

Conclusion

The withdrawal of aprotinin has been a good opportunity to improve our CPB technique. Nevertheless, if ever we had a real fibrinolytic syndrome, particularly during an ECMO period we would be unable to treat it with a specific therapy. To answer the initial question: is there a life after aprotinin in pediatric cardiac surgery?, one can say that pediatric cardiac anesthesiologists and intensivists will continue to improve pediatric cardiac surgery especially when new challenges arise.

References

1. Kern FH, Morana NJ, Sears JJ, Hickey PR. Coagulation defects in neonates during cardiopulmonary bypass. *Ann Thorac Surg* 1992; 54 (3): 541-6
2. Dietrich W, Ebell A, Busley R, Boulesteix AL. Aprotinin and anaphylaxis: analysis of 12,403 exposures to aprotinin in cardiac surgery. *Ann Thorac Surg* 2007; 84 (4): 1144-50
3. Mössinger H, Dietrich W, Braun SL, Jochum M, Meisner H, Richter JA. High-dose aprotinin reduces activation of hemostasis, allogeneic blood requirement, and duration of postoperative ventilation in pediatric cardiac surgery. *Ann Thorac Surg* 2003; 75 (2): 430-7
4. Pouard P, Mauriat P, Ek F, Haydar A, Gioanni S, Laquay N, Vaccaroni L, Vouhé PR. Normothermic cardiopulmonary bypass and myocardial cardioplegic protection for neonatal arterial switch operation. *Eur J Cardiothorac Surg* 2006; 30 (5): 695-9
5. Durandy Y. Usefulness of low prime perfusion pediatric circuit in decreasing blood transfusion. *ASAIO J* 2007; 53 (6): 659-61

Post-resection pulmonary edema

Mert Sentürk

Istanbul Univ Istanbul Medical Faculty, Dep of Anesthesiology, Istanbul, Turkey

Lung injury has long been recognized as a potential complication of lung resection. In 1984, Zeldin reported 10 cases of lung injury following thoracic surgery and coined the phrase “postpneumonectomy pulmonary edema” (PPE). This definition was a very important “first step” to the topic, except the unfortunate terminology (for it can occur also even after very small resections). Looking at its criteria, one can realize that PPE follows a clinical and histopathological course indistinguishable from the acute respiratory distress syndrome (ARDS) (Table 1).

Possible causes of PPE have been defined and determined first in 1995 and then revised in 2002 (table 2), both by Slinger. It can be also realized that these causes have important similarities with the ones of “ventilatory induced (or: associated) lung injury” (VILI or VALI).

Some risk factors have been determined to be associated with the postoperative lung injury: High age, male sex, preoperative pulmonary dysfunction, chronic alcohol consumption are some of the (often unavoidable) preoperative risk factors. Intraoperative risk factors include (not exclusively) extended resection, ventilatory injury, fluid overload, transfusion of blood products. It has been also shown that the genetic factors are playing also an important role.

Table 1. Criteria of PPE

<ol style="list-style-type: none"> 1. Incidence of 2-4% following pneumonectomy. It does occur post-lobectomy but with a lower incidence and better outcome. 2. Significantly increased incidence in right versus left pneumonectomies. 3. Symptomatic onset postoperative day 2-4. Radiographic onset precedes symptoms by 24 h. 4. High mortality rates (> 50%) and resistance to standard therapies for pulmonary edema. 5. Associated with fluid overload, but not clearly cause-effect. 6. Histological picture of ARDS. 7. Associated with a low PAOP and high protein edema fluid suggesting endothelial damage (low pressure pulmonary edema).
--

Table 2. Causes of post-pneumonectomy pulmonary edema (2002): (note that in 1995, volotrauma, right ventricular dysfunction were in “possible” and oxygen toxicity in “questionable” category; and in 2002 moved up to “probable”.)

<p>“probable”</p> <ul style="list-style-type: none"> – Fluid overload – Lymphatic damage – Changes in PCWP – Pulmonary endothelial damage – Volotrauma – Right ventricular dysfunction – Oxygen toxicity <p>“possible”</p> <ul style="list-style-type: none"> – Release of cytokines
--

Although there is a general tendency of decline of the postoperative cardiopulmonary complications after thoracotomies, the incidence of post-thoracotomy lung injury has not shown any decrease in the last decades (2-4 %). Fortunately, the fatality of cases has decreased from almost 100% to less than 40% (thanks to improved postoperative medical management in ICU). Moreover, qualified cardiothoracic surgeons (better to say: thoracic surgeons) achieve better results than non-specialized surgeons. Similarly, improved short and long-term results are also achieved in hospitals with a high volume of any complex procedure, probably as a result of multidisciplinary teams like experienced and organized anesthesia teams, ICU support and acute pain service.

Prevention appears to play a more important role than treatment, for the course has still a high lethality. Unfortunately, some methods to prevent the hypoxemia during one-lung ventilation (OLV) (e.g. high tidal volumes) can increase the probability of lung injury; and

some methods against the lung injury (e.g. lower FiO₂) can increase the risk of hypoxemia. Only a few methods are good for both challenges (e.g. fluid restriction).

“Protective ventilation” during operation and OLV can be considered as the most important prevention method: Low FiO₂, low tidal volumes, PEEP to dependent and CPAP to non-dependent lungs (both CPAP and PEEP should be considered as methods not only to “treat the hypoxia”, but also to prevent the hypoxemia, prevent the atelectotrauma and to allow lower FiO₂; and should therefore be applied routinely), recruitment maneuvers, and avoidance of fluid overload. In the postoperative period, non-invasive ventilation and inhaled beta-2 adrenergic therapy have been shown to be effective in the prevention of lung injury. There are studies examining the effects of some novel techniques and drugs. Especially for the treatment, some improvements to decrease the lethality appear to be inevitable.

References & some suggested readings

1. Licker M et al. Acute lung injury and outcomes after thoracic surgery. *Current Opinion in Anaesthesiology* 2009; 22: 61-67
2. Gothard J. Lung injury after thoracic surgery and one-lung ventilation. *Current Opinion in Anaesthesiology* 2006; 19: 5-10
3. Senturk M. New concepts of the management of the one-lung ventilation. *Current Opinion in Anaesthesiology* 2006; 19: 1-4

Thoracic aortic aneurysm: Anesthesiologist’s view 2009

G. Silvay

Department of Anesthesiology, Mount Sinai School of Medicine, New York, NY, USA

Surgical repair of thoracic aortic aneurysm (TAA) is a complex procedure that poses many surgical and anesthetic challenges.

Early diagnosis and elective treatment of TAA is of great importance. Elective surgeries in specialized institution have the best results. Majority of diagnosis are due to a routine chest X-ray or other radiologic imaging for other medical problems. In the United States over 45,000 people die annually from diseases of the aorta. Diagnosis by size and symptoms, are recently enhanced with additional “non-size criteria” by evaluation of mechanical properties of aorta, symptomatic athero-embolism and biomarkers. It is important to

recommend the type of treatment in a timely manner, regarding from conservative, radical surgical resection or placement of endovascular stent.

Once the decision for operative repair has been made, the patients are assessed in the thorough preoperative evaluation. Our institution utilizes a multi-disciplinary approach in a specialized Pre-Anesthetic Clinic (PAC) for day admission cardiac and major vascular surgery patients. On the day of surgery, the patient is admitted to the hospital in the PAC. Following all routine clinical and administrative necessities, the patient is then escorted to the operating room.

Anesthetic management: Prior to induction of anesthesia, standard ASA monitoring started and antibiotic prophylaxis is initiated. Airway management (for descending thoracic aortic aneurysm repair with double lumen tube) and monitoring are demonstrated in Figure 1. In addition, we are monitoring, if applicable, somatosensory and motor evoked potentials, cerebrospinal fluid pressure, spinal cord perfusion pressure and cerebral oxygen saturation. A brain protection strategy for open surgical repairs of the ascending aorta and/or the aortic arch is an essential component of the operative and anesthetic management. For repair of descending thoracic/thoracoabdominal aneurysm

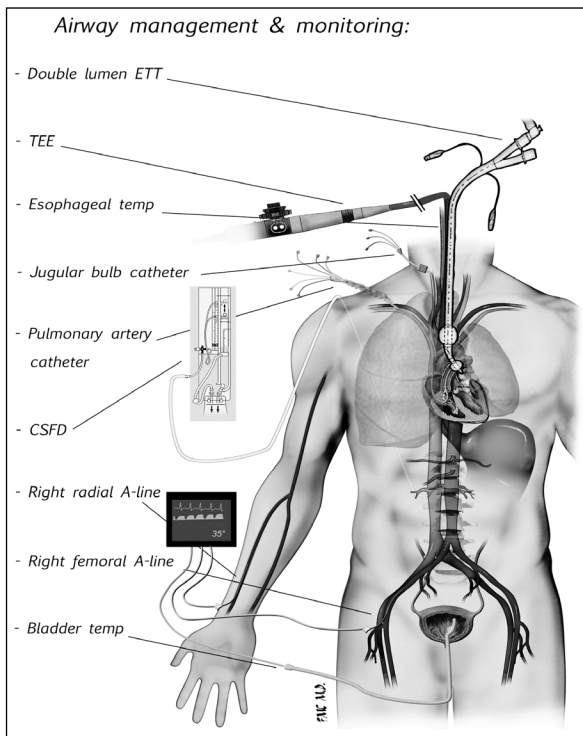


Figure 1

the focus is prevention of spinal cord complication – paraplegia. For different surgical repair deep hypothermic circulatory arrest or distal perfusion is utilized.

From February 1999 to January 2007, 1135 patients underwent different types of surgical repair of thoracic aortic aneurysm. Overall mortality was 6.4%. Patients were divided into three age groups: age < 65 (n=365), 65 - 75 (n=420), and age >76 (n=345). Patients age >76 years had a higher mortality rate, but did not reach significance (95%CI 0.6-3.1 and 0.7-4.6 respectively). Gender did not significantly affect death rate.

A clear understanding of the natural history of TAA is limited by insufficient information from institutional databases as well as different surgical intervention during a variety of aortic diseases. Currently, acute aortic events are still the first clinical symptoms for diagnosis and treatment. Advanced age correlates with a higher operative mortality risk with dissections and rupture being more common in the elderly population. Our group demonstrated that aortic risk in TAA increased by a factor of 2.6 for every decades of life. We demonstrated only a slight, non significant increase in mortality rate in group of patients age over 76 years, compared to a younger population. It is well documented that surgical repair or supra-diaphragmatic repair of aortic aneurysm, can be safely performed in experienced centers, with the mortality below 4% across a wide patient age range. Results support the need for a more proactive intervention in symptomatic geriatric patients as it relates to earlier consideration of elective, rather than emergency operations. Establishments of “Aortic Clinic” will follow the group of patients with TAA and will select time and type of optimal treatment.

At present time no studies exist comparing the results of stent grafting and open surgical treatment for TAA.

References

1. Eleftheriades JA. Thoracic Aortic Aneurysm: Reading the Enemy's Playbook. *World J Surg* 2008; 32: 366-374
2. Coselli JS. Evolution of Thoracic Aortic Operation. 30th Ann.Mtg SCA, Proc. (p92-99) April 2009
3. Griep RB, Griep EB. Spinal Cord Perfusion and Protection During Descending Thoracic and Thoraco-abdominal Aortic Surgery: The Collateral Network Concept. *Ann Thor Surg* 2007; 83: S856-859
4. Svenson LG, Kouchoukos NT, Miller DC. Expert Consensus Document on the Treatment of Descending Thoracic Aortic Disease Using Endovascular Stent-Grafts. *Ann Thor Surg* 2008; 85: S1-41

5. Ullery BW, Peterson JC, Milla F et al. Cardiac Surgery in Select Nonagenarians: Should We or Shouldn't We? *Ann Thor Surg* 2008; 85: 854-860
6. Aortic Surgery and Anesthesia "How to do it". Eds. Chiesa R, Melissano G, Cosseli JS, et al: Publ. Editrice San Raffaele, Milan, Italy. December 2008
7. Etz CD, Zoll S, Kari FA et al. Redo Lateral Thoracotomy for Reoperative Descending and Thoracoabdominal Aortic Repair" A Consecutive Series of 60 Patients. *Ann Thor Surg* 2009 (in press)
8. Silvey G, Stone ME. Repair of Thoracic Aneurysms, with Special Emphasis on the Preoperative Work-Up. *Semin Cardiothor Vasc Anesth* 2006; 10: 11-15
9. Fischer GW. Recent Advances in Application of Cerebral Oximetry in Adult Cardiovascular Surgery. *Semin Cardiothor Vasc Anesth* 2008; 12: 60-69
10. Silvey G, Castillo JC, Chikwe J et al. Cardiac Anesthesia and Surgery in Geriatric Patients. *Semin Cardiothor Vasc Anesth* 2008; 12: 18-28
11. Conrad JS, Cambria RC. Contemporary Management of Descending Thoracic and Thoracoabdominal Aortic Aneurysm. *Ann Thor Surg* 2007; 83: S863-864

Two-lung and one-lung ventilation in patients with chronic obstructive pulmonary disease: The effects of position and FiO_2

L. L. Szegedi

Ghent University Hospital, Belgium

"It is well when the patient is ...reclining upon either his right or left side...But to lie on one's back...is less favourable" (1).

There are absolute indications for one-lung ventilation (OLV) (e.g., hemothorax, unilateral lavage, unilateral cyst), but most procedures are relative indications to facilitate surgical exposure. OLV will induce variable degrees of hypoxemia. The normal response of the pulmonary vasculature is an increase in pulmonary vascular resistance (in the atelectatic lung), caused by the hypoxic pulmonary vasoconstriction (HPV) (2). In the lateral position, the gravity-induced blood flow redistribution is also regularly considered (3-5).

There are studies either contradicting or questioning the primordial role of the gravitational model, concluding that the redistribution of pulmonary blood flow is dominated either by the vascular structure or other factors but gravity (6-8).

Recently, it was demonstrated, that patients with pulmonary hyperinflation, undergoing lung surgery with OLV, had a better arterial oxygen tension (PaO_2) during OLV in the lateral, compared to the supine posi-

tion, and that, independently of the fraction of inspired oxygen used (FiO_2), probably due to another factor than HPV (3).

The purpose of this lecture is to discuss the gravitational redistribution of blood flow during OLV at different levels of FiO_2 .

References

1. Adams F. The genuine works of Hippocrates. Baltimore, ed. Williams and Wilkins, 1939
2. Benumof JL. One-lung ventilation and hypoxic pulmonary vasoconstriction: implications for anesthetic management. *Anesth Analg* 1985; 64: 821-33
3. Bardoczky GI, Szegedi LL, d'Hollander AA et al. Two-lung and one-lung ventilation in patients with chronic obstructive pulmonary disease: the effects of position and $\text{F}(\text{IO})_2$. *Anesth Analg* 2000; 90: 35-41
4. Triantafilou AN, Benumof JL, Lecomwasam HS. Physiology of the lateral decubitus position, the open chest and one-lung ventilation. In: Kaplan JA, Slinger PD (Eds.) *Thoracic Anesthesia* (3rd ed., pp. 71-95) New York: Churchill Livingstone, 2003
5. Arborelius M, Lundin G, Svanberg L, Defares JG. Influence of unilateral hypoxia on blood flow through the lungs in man in lateral position. *J Appl Physiol* 1960; 15: 595-7
6. Chang H, Lai-Fook SJ, Domino KB et al. Spatial distribution of ventilation and perfusion in anesthetized dogs in the lateral position. *J Appl Physiol* 2002; 92: 745-62
7. Glenny RW, Lamm WJE, Albert RK, Robertson HT. Gravity is a minor determinant of pulmonary blood flow distribution. *J Appl Physiol* 1991; 71: 620-9
8. Mure M, Domino KB, Robertson T, Hlastala MP, Glenny RW. Pulmonary blood flow does not redistribute in dogs with reposition from supine to left lateral position. *Anesthesiology* 1998; 89: 483-92

Evidence based treatment of bleeding after cardiac surgery

C. von Heymann

Bleeding is a well known complication after cardiac surgery which significantly contributes to mortality and morbidity of cardiac surgery patients and poses a substantial economic burden to health care givers (1). This underscores the need for effective and safe haemostatic management of bleeding during and after cardiac surgery. Factors which contribute to the risk of bleeding are haemostatic changes due to cardiopulmonary bypass, the use of potent antiplatelet medication prior to surgery, the high incidence of complex cardiac surgical procedures and a growing number of redo surgeries (2). On the other hand and with regard

to recent literature effective haemostatic therapy has to prove its safety when used on a regular basis (3).

This presentation will focus on basic haemostatic changes induced by cardiopulmonary bypass on the one hand and haemostatic treatment during cardiac surgery on the other hand. Therapeutic options either prophylactic or therapeutic will be reviewed and its impact on daily routine evaluated using criteria of evidence based medicine.

Haemostatic changes induced by cardiopulmonary bypass are haemodilution, thrombocytopenia, loss and consumption of clotting factors, activation of the fibrinolytic system (4) and heparin rebound after reversal with protamine (5). In particular, the loss and dilution of platelets and a transient thrombocytic dysfunction seem to play a major role in blood loss in cardiac surgery (6). This is aggravated when cardiac surgery patients are on antiplatelet medication like aspirin and clopidogrel. But, patients on low molecular weight heparin are also at risk of increased blood loss after cardiac surgery.

Haemostatic management after cardiac surgery has to target the underlying cause(s) to be successful and cost efficient. Such management usually comprises a multi-modal approach consisting of the routine use of antifibrinolytics to prevent hyperfibrinolysis and increased blood loss and close monitoring of the activated clotting time to detect an insufficient reversal of heparin or a heparin rebound as early as possible (7). The replacement of fresh frozen plasma, platelet concentrates or clotting factor concentrates will mainly play a role in severely bleeding patients in whom a surgical cause of bleeding has been excluded. Whenever possible an evidence-based approach to treat a bleeding disorder after cardiac surgery should be used to provide a high and safe standard of care. Thus far, the use of clotting factor concentrates in cardiac surgery has not been extensively studied so that the quality of evidence is still low. But, there is data supporting the use of factor concentrates such as FXIII, which bears the potential to reduce bleeding (8). For patients with bleeding refractory to conventional haemostatic treat-

ment, rFVIIa may be an additional option to successfully stop bleeding (9).

So far, only the use of antifibrinolytics has been thoroughly investigated and is recommended using criteria of evidence based medicine to reduce blood loss (10). So far, the use of FFP, platelet and clotting factor concentrates requires further investigation to estimate its potential to reduce bleeding after cardiac surgery.

References

1. Dacey LJ, Munoz JJ, Baribeau YR et al. Reexploration for hemorrhage following coronary artery bypass grafting: incidence and risk factors. Northern New England Cardiovascular Disease Study Group. *Arch Surg* 1998; 133: 442-7
2. Mangano DT, Miao Y, Vuylsteke A, Tudor IC, Juneja R, Filipescu D, Hoefl A, Fontes ML, Hillel Z, Ott E, Titov T, Dietzel C, Levin J; Investigators of The Multicenter Study of Perioperative Ischemia Research Group; Ischemia Research and Education Foundation. Mortality associated with aprotinin during 5 years following coronary artery bypass graft surgery. *JAMA* 2007; 297: 471-9
3. Paparella D, Brister SJ, Buchanan MR. Coagulation disorders of cardiopulmonary bypass: a review. *Intensive Care Med* 2004; 30: 1873-81
4. Dietrich W. Cardiac surgery and the coagulation system. *Curr Opin Anaesthesiol* 2000; 13: 27-34
5. Teoh KH, Young E, Blackall MH et al. Can extra protamine eliminate heparin rebound following cardiopulmonary bypass surgery? *J Thorac Cardiovasc Surg* 2004; 128: 211-9
6. Chung A, Wildhirt SM, Wang S et al. Combined administration of nitric oxide gas and iloprost during cardiopulmonary bypass reduces platelet dysfunction: a pilot clinical study. *J Thorac Cardiovasc Surg* 2005; 129: 782-90
7. Jambor C, Bremerich D, Moritz A et al. Management of hemostasis disorders after extracorporeal circulation: A clinical therapy algorithm. *Anaesthesist* 2008
8. Godje O, Gallmeier U, Schelian M et al. Coagulation factor XI-II reduces postoperative bleeding after coronary surgery with extracorporeal circulation. *Thorac Cardiovasc Surg* 2006; 54: 26-33
9. Karkouti K, Beattie WS, Crowther MA et al. The role of recombinant factor VIIa in on-pump cardiac surgery: proceedings of the Canadian Consensus Conference. *Can J Anaesth* 2007; 54: 573-82
10. Henry DA, Carless PA, Moxey AJ, O'Connell D, Stokes BJ, McClelland B, Laupacis A, Fergusson D. Anti-fibrinolytic use for minimising perioperative allogeneic blood transfusion. *Cochrane Database Syst Rev* 2007; 4: CD001886