Acknowledgements

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continued clinical research. However, in the climate of the 1950s, work continued until some acceptable level of mortality was achieved. Even as late as the 1980s, an acceptable and delivered mortality for corrective infant open-heart surgery of 40% or greater was normal both in the UK and abroad. However, at the same time, a new wave of paediatric cardiac surgery teams originating from a few pioneering centres including those in the UK was achieving published mortality figures of less than 5%. The key to this success has been advances in cardiology, cardiac surgery, anaesthesia, intensive care combined with a high degree of immediacy when problems arise and a tight team that can respond as a composite unit to convert the inevitable problems and critical situations into good outcomes.

Recent developments in paediatric cardiac anaesthesia have highlighted the aspects of balancing relatively high-risk aspects of paediatric cardiac anaesthesia with attempts to significantly improve postoperative cardiac recovery and outcomes. While the heterogeneity of the disease conditions make it difficult to deliver large prospective outcome studies on a single aspect or treatment, it is still possible with smaller focused studies to investigate whether there is reasonable evidence of value. Nevertheless, in a specialty where outcomes can be easily measured and compared across units in terms of death and major morbidity, there is a highly conservative approach to change and resistance to try new techniques that may have high risk and high gain. To move forward, it is therefore necessary in the initial phase of development for one or two units to pioneer and refine a technique, look for evidence of benefit (or not) in a controlled fashion before broadening its use. Recent examples using this approach have included ultra-fast-track paediatric anaesthesia, the use of central neuraxial block, and perioperative management of the surgery for infants with hypoplastic left heart syndrome.

Fast-track paediatric cardiac surgery with extubation on the operating table or shortly afterwards can seem rash. The 1980s and 1990s were dominated by techniques that attempted to ablate stress responses using high-dose opioids and necessitated prolonged postoperative ventilation. However, as data emerged on the benefits of early mobilization in both cardiac and non-cardiac surgery in adults, this has been re-examined in paediatrics. Several groups have pioneered techniques of early extubation, not only for older children having simple open-heart surgical procedures, but also for infants having more complex surgery. More specifically, clear data have emerged that for some lesions including Fallot’s tetralogy and surgery for single ventricle physiology, there are benefits in terms of haemodynamic and reduction in postoperative complications.

Anaesthesia techniques require the understanding of drug effects particularly in the context of bypass, and surgery of the child with heart disease. One of the more radical attempts to try to associate regional anaesthesia stress responses and outcome was the study of fetal lambs who were exteriorized from the uterus and placed on bypass. The authors found that total spinal anaesthesia administered via the cisterna magna completely blocked the stress response to surgical manipulation and CPB and that it was associated with improved survival of the fetoplacental unit after bypass. More recently, in adults, a prospective randomized study was undertaken to evaluate the use of intrathecal morphine and bupivacaine during adult cardiac surgery and compared this with a conventional i.v. opioid technique. The spinal group had reduced stress responses with a higher cardiac index, lower pulmonary vascular resistance, and reduced atrial β-receptor dysfunction after surgery, but the lower pulmonary and systemic vascular resistance was at the cost of reduced systemic arterial pressure and increased need for vasoconstrictors. High spinal anaesthesia has also been used in paediatric cardiac anaesthesia for neonates and small children undergoing surgery with CPB. Humphreys and colleagues prospectively compared a large dose fentanyl group similar to the earlier Anand studies and compared this with a high-dose spinal anaesthesia group using an indwelling spinal catheter technique. Spinal anaesthesia was associated with significantly reduced plasma norepinephrine and epinephrine concentrations, plasma lactate concentrations, and interleukin-6 in patients undergoing prolonged CPB, while no differences in other cardiovascular parameters were demonstrated. The reduced lactate and interleukin (IL)-6 response gave some potential indication of benefit: catecholamines increase the expression of pro-inflammatory cytokines such as IL-6, and high serum concentrations of IL-6 and lactate are correlated with increased morbidity post-CPB in infants and children.

The anaesthetic management of hypoplastic left heart syndrome has evolved over 20 yr and is part of a continuing team process. This high-risk activity in which the left ventricle, aorta, and mitral valve are undeveloped requires unorthodox ventilation and management of the cardiovascular system to carefully balance systemic and pulmonary shunt fractions. The right ventricle is fragile in the neonatal period particularly as it is needed to maintain not only the pressure and flow associated with the systemic circuit but also to provide adequate pulmonary blood flow. In these patients, inotropic drugs may initially give improved headline haemodynamic values, but ultimately, this can lead to fatigue of the ventricle, exhaustion of energy substrates, and death. The use of additional measures of assessment of cardiac output such as near-infrared spectrometry (NIRS), venous saturation, and non-invasive cardiac output is helping to guide this delicate balance in perioperative management. This condition is a good example of the necessity for immediacy of action when required and the understanding that no one is ‘unfit for anaesthesia and surgery’ but that it is simply a question of ascribing an individual risk and potential benefit to the planned procedure within the individualized context. The risk/benefit ratio of technique selection may not be immediately obvious, particularly if the benefits are not identifiable until well after the anaesthesia has ended. In the last 20 yr, there have been major advances in the understanding...
of the management of the very low birth weight infant. A careful long-term follow-up assessment of neurodevelopment over years has demonstrated that relatively minor deviations from ideal physiological parameters during care on the neonatal intensive care unit (NICU) may have profound effects that may not emerge until months or years later. Hypotension, hypoxemia, hypoglycaemia and even relatively brief periods of mild hypoglycaemia have been associated with significant long-term outcomes. In addition, the mode of ventilation has influence on the incidence and severity of bronchopulmonary dysplasia and chronic lung disease.

Clearly, anaesthesia management of these low birth weight infants undergoing ductal ligation requires a very high level of control to aim to minimize major deviations in ventilation, arterial pressure control, and blood biochemistry within the limitations of the surgery and anaesthesia. These include balancing inspired oxygen concentration and arterial saturations through the changes imposed by thoracotomy and partial lung deflation, measuring and controlling P\textsubscript{a}CO\textsubscript{2}, and optimizing cerebral blood flow through the use of NIRS, controlling ventilation with a neonatal ventilator rather than using manual ventilation, and maintaining tight arterial pressure control at all times. Simply surviving the procedure is not enough: the longer term morbidity and quality of life while not often considered in the context of a short anaesthetic for ductal ligation is important. This approach of ‘aggregation of marginal gains’ which has been a successful philosophy for high-level sporting achievements needs to be translated into complex medical environments, although the demonstration of benefit may be much more difficult to prove than in the simpler world of competitive sport.

**Declaration of interest**

None declared.

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