Institution: University College London

Unit of Assessment: 1 – Clinical Medicine

Title of case study: Improved surgical outcomes achieved through perioperative circulatory optimisation guided by oesophageal Doppler

1. Summary of the impact

As a result of research undertaken by Professor Mervyn Singer and colleagues at UCL, the oesophageal Doppler haemodynamic monitoring device is now a standard of care in intensive care units and operating theatres. The research underpinned the development of the CardioQ Oesophageal Doppler Monitor that guides optimisation of the circulation in critically ill and perioperative patients. In multiple studies its use has led to significant reductions in postoperative complication rates and length of stay in patients undergoing high-risk surgery. Over 500,000 patients have now benefitted from this technology that, between 2008-13, generated over £33m in sales for its manufacturer, Deltex Medical. The device is recommended in NICE guidance and has been identified by the Department of Health as one of six high impact innovations to be implemented fully across the NHS.

2. Underpinning research

In the late 1980s, the CardioQ Oesophageal Doppler Monitor was conceived by Mervyn Singer while a registrar at Mount Vernon Hospital. He then validated the device and performed proof-of-concept studies during his research fellowship at St George's Hospital Medical School. Work at UCL by Singer (as Lecturer/Senior Lecturer/Reader/Professor) between 1993 and 2004 further validated the device and, crucially, assessed its utility through a series of studies, including three of the early perioperative outcome RCTs. This work done at UCL underpinned the commercial development of the device and its widespread adoption since.

The device utilises a Doppler ultrasound probe inserted via the mouth into the oesophagus. The probe is connected to a monitor that displays flow velocity waveforms of blood being pumped down the descending thoracic aorta. Correct focussing of the probe is readily and reliably achieved within just a few minutes, and can be performed by either a doctor or nurse. Integral software, incorporating a nomogram developed by Singer, computes in real time a close estimate of absolute left ventricular cardiac output and, from the waveform shape, considerable information on left ventricular filling, contractility and afterload. These data can be used to quickly detect any deterioration in circulatory status, and to guide optimal fluid and drug therapy.

Ten studies have been performed at UCL, including assessments of the circulatory stress induced by chest physiotherapy, transurethral prostatectomy and cardiac surgery (with demonstration of its prognostic utility), and optimisation of mechanical ventilation settings. Importantly, three of the studies were single-centre, randomised controlled trials (RCTs) in patients undergoing haemodynamic optimisation either during **[1]** or after **[2]** cardiac surgery, or during intraoperative repair of fractured hips **[3]**. The first study was performed by Monty Mythen (then Clinical Research Fellow, now Professor at UCL) and the latter two were led by Singer. All three studies reported significant reductions in postoperative complications and hospital stay in patients optimised by oesophageal Doppler, as compared to patients receiving standard-of-care.

A recent systematic review/meta-analysis of perioperative optimisation studies reported on nine oesophageal Doppler perioperative optimisation studies, demonstrating a major reduction in post-operative complications through its use (odds ratio [95% CI] 0.41 [0.30–0.57]) (Hamilton et al).To assess the generalisability of these results, the NHS Technology Adoption Centre organised a before-after study in three UK hospitals (including the Whittington Hospital, London) comparing outcomes in 649 surgical patients after implementation of the CardioQ technology against 658 matched cases before implementation. Total length of stay was reduced by 3.7 days across each

site (Kuper et al).

All of the UCL studies were funded internally with the exception of Ref 3 below where Deltex Medical (the manufacturer of CardioQ) provided an unrestricted educational grant.

3. References to the research

[1] Mythen MG, Webb AR. Perioperative plasma volume expansion reduces the incidence of gut mucosal hypoperfusion during cardiac surgery. Arch Surg. 1995 Apr;130(4):423-9. http://dx.doi.org/10.1001/archsurg.1995.01430040085019

[2] Sinclair S, James S, Singer M. Intraoperative intravascular volume optimisation and length of hospital stay after repair of proximal femoral fracture: randomised controlled trial. BMJ. 1997 Oct 11;315(7113):909-12. http://dx.doi.org/10.1136/bmj.315.7113.909

[3] Poeze M, Ramsay G, Greve JW, Singer M. Prediction of postoperative cardiac surgical morbidity and organ failure within 4 hours of intensive care unit admission using esophageal Doppler ultrasonography. Crit Care Med. 1999 Jul;27(7):1288-94. http://dx.doi.org/10.1097/00003246-199907000-00013

[4] McKendry M, McGloin H, Saberi D, Caudwell L, Brady AR, Singer M. Randomised controlled trial assessing the impact of a nurse delivered, flow monitored protocol for optimisation of circulatory status after cardiac surgery. BMJ. 2004 Jul 31;329(7460):258. http://dx.doi.org/10.1136/bmj.38156.767118.7C

[5] Dark PM, Singer M. The validity of trans-esophageal Doppler ultrasonography as a measure of cardiac output in critically ill adults. Intensive Care Med. 2004 Nov;30(11):2060-6. http://dx.doi.org/10.1007/s00134-004-2430-2

[6] Atlas G, Brealey D, Dhar S, Dikta G, Singer M. Additional hemodynamic measurements with an esophageal Doppler monitor: a preliminary report of compliance, force, kinetic energy, and afterload in the clinical setting. J Clin Monit Comput. 2012 Dec;26(6):473-82. http://dx.doi.org/10.1007/s10877-012-9386-5

4. Details of the impact

In developing the device, Singer worked closely with the manufacturer (formerly Doptex, now Deltex Medical), a British company based in Chichester. This close collaboration allied his clinical and translational expertise with their engineering and technical skills. The device, now marketed as the CardioQ, has *"changed the way in which doctors can care for patients having major surgery or in intensive care. It allows doctors to intervene quickly and safely based on small changes in circulating blood volume and so avoid the dangers of reduced oxygen delivery"* **[a]**.

To date, more than 500,000 patients have benefitted from the use of the CardioQ in surgery and in intensive care. By the end of 2012, a total of 926 monitors had been installed in the UK and monitors have been sold widely in many other countries including the US, Canada, South America and Continental Europe **[a]**. In the period 2008-13 this amounted to over £33m in sales for Deltex **[b]**. The company employs around 65 people, mostly in the UK, and the CardioQ is their sole product.

The outcome benefits (reduced complications, shorter ICU and hospital stay) accruing from the perioperative optimisation studies were evaluated and endorsed independently by the US Agency for Healthcare Research and Quality **[c]** and the NIHR Health Technology Assessment Programme **[d]**. In March 2011 NICE published its Medical Technologies Guidance (MTG3) recommending the use of oesophageal Doppler monitoring (ODM) in high-risk surgery. NICE estimated that its use could save around £1,000 each time it is used for high-risk surgery, and up to £400m per year for the NHS as a whole **[e]**.

In the same year, the NHS Innovative Technology Adoption Procurement Programme (ITAPP) selected oesophageal Doppler-guided intra-operative fluid management as one of three technologies for wider adoption by the NHS in England **[f]**. Later that year, the NHS Innovation Health & Wealth Review named ODM as one of six high impact innovations and called for the widespread implementation of ODM for fluid management in surgery, stating that this technology *"can reduce mortality rates for elective procedures, improve the quality of care for more than 800,000 patients a year, and save the NHS at least £400m annually"* **[g]**. This was reported in the media at the time, including on the BBC News website **[h]**.

In May 2012, the NHS National Technology Adoption Centre published its Intraoperative Fluid Management Technologies (IOFMT) Adoption Pack to encourage adoption throughout the NHS as a recommended High Impact Innovation **[i]**. Hospital trusts have to implement ODM at projected target levels in 2013/14 or lose access to their CQUIN payments, which make up 2.5% of their budget.

Looking outside the UK, the device has been adopted or is under formal evaluation by health regions/large hospital groups in the USA, France, Spain, and Canada. The Entralgo Agency in Spain have evaluated the device and confirmed its utility. In April 2013, the US Centres for Medicare and Medicaid Services (CMS) granted ODM its own unique code for physician reimbursement. In addition, CMS set a standard amount of $101 that it will reimburse US doctors for each use of an ODM probe in either surgery for patients requiring intra-operative fluid optimisation or for ventilated patients in intensive care. This is a very significant development for the ODM in the USA and very rare that the CMS grant an individual technology with such a code (especially to a small British company) **[j]**.

In May 2013, the professional body for anaesthetists in France Société Française d'Anesthésie et de Réanimation ('SFAR') published new guidelines setting out recommended fluid management best practice for its members. These guidelines make it clear that ODM-guided fluid management should be used in all high risk surgery in France, estimated to cover circa 750,000 patients a year. All of these recommendations are graded in the highest category '1+', meaning that SFAR members are expected to comply because the evidence level is high, and that future evidence is unlikely to change the conclusions from the current evidence. In France clinical guidelines from professional societies determine the standards expected of their members based on clinical benefit. The recommendations are based on the ODM evidence and the guidelines make it clear that this evidence should not be assumed to apply to alternative technologies. The recommendations apply to all high risk surgery, defined as surgery with an increased risk of post-operative complications due to either the health of the patient or the nature of the surgery; typically this excludes minor day-case surgery and surgery lasting fewer than two hours with low levels of post-operative complication **[k]**.

Deltex Medical won the National Outstanding Achievement category in the 2013 UK Healthcare Business Awards held at the NHS Healthcare Innovation Expo **[l]**.

5. Sources to corroborate the impact

[a] Deltex Medical website: http://www.deltexmedical.com/index.html and 2012 annual report http://www.deltexmedical.com/downloads/2012report&accounts.pdf

[b] Sales figures supplied by Deltex – available on request.

[c] Agency for Healthcare Research and Quality Technology Assessment Program. Esophageal Doppler Ultrasound-Based Cardiac Output Monitoring for Real-Time Therapeutic Management of Hospitalised Patients; January 2007 http://www.cms.gov/medicare-coverage-database/details/technology-assessments-details.aspx?TAId=45&bc=BAAgAAAAAAAA& (See refs 10, 47, 48 which are papers in section 2 above; also refs 1 and 64 are work done at UCL by the same individuals).

[d] Mowatt G, Houston G, Hernández R, et al. Systematic review of the clinical effectiveness and cost-effectiveness of oesophageal Doppler monitoring in critically ill and high-risk surgical patients. Health Technol Assess. 2009; 13: iii-iv, ix-xii, 1-95 http://www.hta.ac.uk/fullmono/mon1307.pdf

[e] CardioQ-ODM (oesophageal Doppler monitor) (MTG3) http://guidance.nice.org.uk/MTG3 (accessed 21st May 2012)

[f] See, for example, plans for adoption in the East Midlands, which explain the wider national context: http://www.tin.nhs.uk/innovation-nhs-east-midlands/product-and-technology-adoption-campaigns/the-oesophageal-doppler/

[g] Innovation, Health and Wealth 2011 http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_134597.pdf

[h] BBC News coverage: http://www.bbc.co.uk/news/health-12899316

[i] NHS Technology Adoption Centre: http://www.ntac.nhs.uk/Publications/TechnologyAdoptionPacks/Intra_Operative_Fluid_Management/Intra_Operative_Fluid_Management.aspx

[j] Press release from Deltex Medical giving details of the newly announced physician reimbursement in USA http://www.deltexmedical.com/announcements/2013_04_10.pdf

[k] Vallet B, Blanloeil Y, Cholley B, Orliaguet G, Pierre S, Tavernier B. Stratégie du remplissage vasculaire périopératoire (Guidelines for perioperative haemodynamic optimization). Ann Fr Anesth Reanim. 2013 Jun;32(6):454-62 http://dx.doi.org/10.1016/j.annfar.2013.04.013

[l] UK Healthcare Business awards: http://www.sehta.co.uk/2013/03/13/deltex-wins-medilinkuk-national-outstanding-achievements-award/