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PRACTICE

QUALITY IMPROVEMENT REPORT

Intraoperative fluid management guided by oesophageal Doppler monitoring

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Abstract

Problem Fluid management during major surgery poses a challenge to the surgical team as postoperative complications are often related to giving the wrong amount of intravenous fluid. Postoperative morbidity can be reduced by using the oesophageal Doppler cardiac output monitor to individualise fluid administration, but this technology has not been widely adopted.

Design A campaign for adopting this technology in major surgical specialties explored clinical and managerial barriers throughout the procurement and implementation process. We compared patient outcomes 12 months before implementation and after implementation.

Setting Three large hospitals in England with different size, geographical location, and case mix.

Strategies for change Project leads at each site included a consultant anaesthetist, a divisional manager, and an audit facilitator. A business case was prepared by each team with support from NHS Technology Adoption Centre, allowing senior management to overcome the unequal spread of costs versus benefits. A survey of anaesthetists revealed concerns about familiarity with the device, which we dealt with by clinicians volunteering to "champion" the technique, supported by standard training provided by the manufacturer. We encouraged appropriate use of the technology by collecting intraoperative patient related data and postoperative patient outcomes and by giving regular, timely feedback.

Key measures for improvement The key outcome measure was length of hospital stay. In-hospital mortality, readmission, and reoperation rates were also recorded. Process measures were use of monitors and change in stroke volume during surgery.

Effects of the change We compared 649 patients after implementation across all sites with 658 matched cases before implementation. Use of Doppler increased from 11% to 65% of eligible operations, with a 3.7 day reduction in total length of stay. Length of stay was reduced at each site, and in most specialties. Concurrent improvements in patient care could have contributed to these findings. The only sign of harm from the intervention was one episode of pulmonary oedema. Mortality, readmission, and reoperation rates all fell non-significantly.

Lessons learnt Managerial barriers consisted of silo budgeting, difficulties with preparing a business case, and fears about uncontrolled implementation. By collecting outcome data, we convinced senior managers to support and sustain investment. Clinical barriers consisted mainly of scepticism regarding clinical effectiveness and worries about training. Clinicians "championing" the technology took on responsibility for data collection, education, advocacy, and spanning boundaries. When barriers to adoption of oesophageal Doppler monitoring are overcome, outcome improvements suggested by research can be replicated in the real world. The project generated a web based guide (www.howtowhyto.nhs.uk) to provide tools and resources to support implementation.

Context

Effective intraoperative fluid therapy is an essential component of enhanced recovery programmes for patients having major surgery.[1] Conventional haemodynamic monitoring of pulse and blood pressure fails to detect occult hypovolaemia, which occurs in many surgical patients[2] and contributes to inadequate tissue perfusion, leading to organ dysfunction and postoperative complications.[3] On the other hand, large volumes of intravenous fluid may cause complications due to unwelcome tissue oedema. After major surgery many patients experience complications, which are associated with prolonged hospital stay and adverse long term outcomes.[4 5] The oesophageal Doppler monitor (Deltex Medical, Chichester, UK) measures stroke volume, allowing

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the anaesthetist to target intravenous fluid replacement to an individual's needs, reducing the risk of giving too much or too little fluid. Evidence from seven randomised controlled trials, a meta-analysis, and a health technology assessment and procurement review shows that such individualised "goal-directed" fluid therapy with oesophageal Doppler monitoring reduces complications and length of stay after major surgery.[6-14]

The NHS Technology Adoption Centre (NTAC) has a remit to facilitate implementation of proved medical technology that can benefit patients and improve the efficiency of systems. The centre supported the implementation of fluid administration guided by oesophageal Doppler monitoring at three hospitals chosen for their different size, geographical location, and case mix. The Whittington is a university associated, district general hospital in London; Royal Derby Hospital is a large regional hospital; and Manchester Royal Infirmary is a tertiary centre. Patient groups included in the implementation programme varied at the three sites (table 1). Various minimally invasive devices for monitoring cardiac output had been trialled at each centre, but no structured programme of implementation had been carried out and actual use of the devices was sporadic.

Outline of the problem

Although clinical research has indicated that patients having major surgery are likely to benefit from intraoperative fluid management guided by oesophageal Doppler monitoring, its use has been patchy. The project aimed to identify and overcome barriers to the procurement and implementation of oesophageal Doppler monitoring. We also wanted to determine whether benefits suggested by research could be obtained in practice.

Key measures for improvement

The key patient outcomes were length of hospital stay and postoperative stay. As indicators of potential harm, we assessed oesophageal trauma and pulmonary oedema, along with readmission and reoperation rates and inpatient mortality. Process measures included use of monitors, volume and type of intravenous fluids administered, perioperative change in stroke volume, and the use of invasive arterial and central venous monitoring.

Gathering information

We systematically assessed the barriers to procurement and the impact of implementation at each site. Qualitative data regarding barriers to implementation of oesophageal Doppler monitoring were recorded and discussed at regular meetings of the project group and local clinical teams. Attitudes of consultant and trainee anaesthetists towards the benefits and risks of this monitoring were surveyed anonymously in Manchester before implementation.

We compared prospective data from consecutive patients in the year after implementation with retrospective data from controls matched by specialty and severity of operation, identified from hospital record systems, from the year before implementation. Consultant anaesthetists and audit facilitators collected information on process and outcome measures preoperatively, intraoperatively, and postoperatively by using a standard form. We estimated the risk of complication and death using the POSSUM surgical scoring system, which incorporates patient related and surgical risk factors.[15] Following advice from York Health Economics Consortium, our statistical analysis used the *t* test for independent samples. For comparisons of smaller numbers (<100) we used the Mann-Whitney test, and for count data we used the χ^2 test.

Analysis and interpretation

At all three sites, previous business cases prepared by clinicians had failed to be accepted by the hospital management. On review, these unsuccessful business cases did not illustrate how reducing the length of stay could be valued in terms of additional income generation or cost reduction. A recurrent theme was silo budgeting, where directorate managers responsible for fixed, non-transferable budgets were unable to reconcile the unequal spread of costs and benefit across directorates. Managers were wary about the cost of unrestricted use of consumables.

Although most anaesthetists surveyed were prepared to accept that oesophageal Doppler monitors were useful, many were concerned that they lacked sufficient training to use the devices confidently. Others questioned whether the results of randomised trials would apply to their individual practice, for example, wondering whether improvements in patient care would fail to reduce length of stay due to inefficient custom and practice on the surgical ward.

Strategy for change

At each site, a project team combining a lead clinician, managers, and audit facilitator devised a project plan together, with support from an NTAC programme manager. Regular meetings of the project teams allowed common barriers and solutions to be identified. Senior managers at each site were engaged to help overcome problems arising from silo budgeting. Directorate managers prepared business cases, with clinical input and a cost-activity model devised by NTAC based on reduction in length of stay. Controlled implementation and probe requirements were projected from previous year's surgical activity. To provide a common price for the project, purchase of Doppler monitors and probes was negotiated between NTAC, a regional NHS procurement hub, and the manufacturer. However, full funding for monitors and disposables came from within each trust's surgical budget. The manufacturer provided written information to support preparation of the business case and standard training in using monitors, but had no active or observational role in study design, data collection, or analysis.

At each site NTAC funded a nurse or audit facilitator to collect data, and implementation was encouraged by giving regular feedback to the anaesthetists. Data on Doppler use and patient outcomes were compared with controls matched for surgical specialty and type of operation, from the 12 months before implementation. Regular meetings between anaesthetists and the project team at each site encouraged feedback and helped troubleshooting. After training in the classroom and theatre, anaesthetists were encouraged to use oesophageal Doppler monitoring in all eligible cases.

The approach to implementation was tailored to the diverse surgical activity at each site. At Royal Derby Hospital, monitoring was implemented in colorectal surgery. The colloid used was succinylated gelatin (Gelofusine; B Braun Medical, Sheffield, UK). Overlapping committee responsibilities were an important hurdle; the equipment, change in practice, audit, and directorate management committees were all involved in conducting the project. An executive sponsor at the trust's board level proved crucial in encouraging clinicians and managers to work together and generate organisational momentum. A reorganisation that gave one manager responsibility for both surgical wards and operating theatres helped overcome silo budgeting.

At Manchester Royal Infirmary, Doppler use was encouraged for a wide range of major elective and emergency surgical procedures, but to maintain control of costs, implementation was limited to a subset of clinical teams. Fourteen consultant anaesthetists volunteered to champion Doppler use and report perioperative outcomes. These data were compared with procedures of similar severity undertaken by the same clinical teams in the 12 months before implementation. The colloid used was hydroxyethyl starch (Volulyte; Fresenius Kabi, Runcorn, UK).

At the Whittington Hospital, oesophageal Doppler monitoring was implemented in colorectal and orthopaedic surgery (table 1). The colloid used was succinylated gelatin. Usage by 18 consultants and two staff grades was encouraged in all eligible cases. In addition to training for permanent staff, instruction was introduced into the trainee induction programme. At the Whittington and in elective colorectal surgery only, Doppler use was implemented as part of a multidisciplinary multimodal enhanced recovery programme.[1]

Effects of change

We compared 649 patients who had major surgery after the implementation of fluid administration guided by oesophageal Doppler monitoring (intervention group) with 658 patients (controls) who had had similar operations in the preceding 12 months. Preoperative POSSUM scores and urgency of surgery were similar in the two groups (table 2).

After implementation, oesophageal Doppler monitoring was used in 65% of operations, compared with 11% before implementation. Although Doppler use was encouraged it could not be mandated, so this represented a substantial increase. No anaesthetists refused to use the Doppler monitor or stated that they felt unable to use the monitor after training.

In the post-implementation group, stroke volume increased from 80.7 ml to 97.2 ml from the start to the end of the case (table 3). This increase of 16.5 ml in stroke volume is consistent with correcting physiological hypovolaemia.[16]

The oesophageal Doppler monitor augments clinical judgment to allow individualised fluid administration (figure). We found a modest but significant mean difference in total colloid volume compared to before implementation, coupled with a wide standard deviation, indicating that some patients required much more fluid than others. This concurs with research showing that the optimal fluid volume for perioperative patients varies widely and that a balanced approach reduces complications.[17] The differences in fluid volumes before and after implementation are comparable with the published studies of oesophageal Doppler monitoring, which have also shown that such fluid optimisation improves organ perfusion[3 16] and reduces the stress response to surgery, including release of interleukin-6,[9] thus reducing length of stay.[13 18] Many anaesthetists reported that after oesophageal Doppler monitoring was implemented they felt more confident giving intravenous fluid proactively.

Table 3 shows the use of cardiovascular monitoring. Use of arterial catheters did not change, but use of central venous catheters was reduced by 10% after Doppler monitoring was implemented.

The observed lengths of stays before implementation were typical of national outcomes for the type and urgency of surgery studied. In Derby, where only elective colorectal surgery was examined, the mean length of stay before implementation was 11.9 bed days. This represented current practice since in 2008-9 (hospital episode statistics for 161 hospitals in England); the national mean length of stay for colectomy was 11.2 bed days and for rectal resection was 13 bed days. At the Whittington and Manchester hospitals, both elective and emergency surgery were included, and more major surgery was undertaken (table 1), so length of stay was longer. Overall, after implementation the mean length of hospital stay fell by 3.6 days (from 18.7 to 15.1 days; P=0.002) and postoperative length of stay fell from 17.2 days to 13.6 days (P=0.001) (table 4). The mean length of stay in critical care was similar in control and intervention patients (data not shown).

Signs of harm arising from the implementation were absent. Critical care readmission, hospital readmission, reoperation, and in-hospital mortality were slightly lower after implementation (table 5). One episode of pulmonary oedema occurred in a patient with sepsis and chronic renal failure.

This non-randomised "before and after" project explored the challenges and the effectiveness of a new approach to implementing technology and its impact on important patient outcomes. Despite matching for specialty and severity of operation, the control and implementation groups had differences in age and physical status scores; however, the perioperative risk indicator (POSSUM, which incorporates age) was similar in the groups, so similar outcomes would be predicted.

Results could have been confounded by other changes occurring over the same time period. However, both total and postoperative length of stay fell on all three sites and these reductions were significant on two of the sites, strengthening the evidence for an effect of the intervention.

At the Whittington, in elective colorectal surgery only, a multidisciplinary enhanced recovery programme was introduced and may have contributed to the observed improvement. No other enhanced recovery pathway elements were introduced in Manchester or Derby. With all elective colorectal patients at the Whittington excluded, the reduction in postoperative stay for remaining patients remained unchanged (3.6 days; P=0.003). We did not identify other important confounding factors—for example, availability of critical care beds did not change, nor did admission policy or provision of outreach.

One trial found that oesophageal Doppler monitoring may not benefit patients receiving enhanced recovery care,[19] but excellent results have been reported within an enhanced recovery colorectal pathway using such monitoring.[20]

Any implementation study of this type is vulnerable to a Hawthorne effect, whereby performance improves as a result of close observation. So although use of oesophageal Doppler monitoring rose from 11% to 65%, with patients achieving a 20% rise in stroke volume, these improvements may not be replicated when clinical performance is not being closely observed.

Even though patient groups differed at the three sites in the type and urgency of surgery, a consistent benefit was seen. This indicates that implementing oesophageal Doppler monitoring may produce benefits in diverse healthcare settings.

Next steps

Patient outcomes improved after managerial and clinical barriers to implementation were identified and overcome. Preparation of the business case was improved by partnership with local managers, coupled with external support from NTAC and supportive literature from the manufacturer. Illustrating the benefits from reductions in length of stay required two business models, based either on increasing activity or on reducing bed base with resulting cost savings. Silo budgeting, with unequal spread of costs and benefits across directorates, was overcome with the support of senior executives.

Clinical reluctance to adopt oesophageal Doppler monitoring technology revolved around three aspects: scepticism about utility; confidence with using the monitor; and reluctance to change usual practice. These issues were overcome by a "campaign" comprising departmental meetings, reminder emails, education and training of senior and junior doctors separately, and advocacy by clinical champions to support use of the technology. The project team kept records of anaesthetists who had undergone the standard training.

The stroke volume maximisation technique (figure) introduced with oesophageal Doppler monitoring facilitates individualised fluid administration. We found a small increase in colloid administered after implementation, but a wide standard deviation, indicating that some patients needed more fluid than others to maintain fluid balance.[17] Many anaesthetists reported that after oesophageal Doppler monitoring was implemented they felt more confident giving intravenous fluid proactively. It may be that early administration of colloid is as important as the total volume, with monitoring preventing giving excessive fluid. The project team did not dictate whether anaesthetists should continue to use traditional methods of assessing volume status, such as central venous pressure. Nonetheless, the use of central venous catheters fell by 10%, perhaps as a result of recognition of the limitations and associated risks of this practice.[21]

This project, commissioned and facilitated by NTAC, shows that organisational support and a systematic approach to technology adoption, can help clinicians implement evidence based care that benefits patients. We have helped NTAC produce a guide (www.howtowhyto.nhs.uk) that contains links to clinical research, teaching resources, details of the project sites and patient outcomes, and an interactive business case with cost-activity modelling.

Individualised fluid therapy has been adopted as one of the recommended elements for major elective surgical pathways by the National Enhanced Recovery Programme.[1] The project sites have also received regional innovation funding to help support diffusion and adoption of oesophageal Doppler monitoring.

Independent statistical advice was provided by York Health Economics Consortium at York University.

Contributors: CC, DC, SG, and MK conceived and designed the project. All authors collected, analysed, and interpreted the data. CC, DC, SG, MK, and TQ drafted the manuscript and take full responsibility for its integrity. DC and MK are the guarantors of the project.

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Tables

Table 1| **Surgical specialties in which oesophageal Doppler monitoring was implemented**

Surgical specialty	Timing of surgery
Royal Derby Hospital:	
Colorectal	Elective and urgent
Whittington Hospital:	
Colorectal	Elective and urgent
Orthopaedics	Elective and urgent
Manchester Royal Infirmary:	
Colorectal	Elective and urgent
Upper gastrointestinal	Elective
Orthopaedics	Elective
Gynaecology	Elective
Kidney or pancreas transplant	Urgent
Urology	Elective

Table 2| Preoperative data for surgical patients before and after the implementation of fluid administration guided by oesophageal Doppler monitoring. Values are percentages unless specified otherwise

	Control (n=658)	Intervention (n=649)
Age		
≤60	196 (29.8)	237 (36.5)
61-70	175 (26.6)	167 (25.7)
≥71	287 (43.6)	245 (37.8)
Surgical specialty:		
Colorectal	339 (51.5)	355 (54.7)
Gynaecological	4 (0.6)	9 (1.4)
Orthopaedic	139 (21.1)	133 (20.5)
Kidney or pancreas transplant	48 (7.3)	33 (5.1)
Upper gastrointestinal	79 (12.0)	55 (8.5)
Urology	21 (3.2)	45 (6.9)
Vascular	28 (4.3)	19 (2.9)
Mean (SD) POSSUM score	34.3 (8.3)	34.0 (8.5)
ASA physical status grade:	83 (12.6)	108 (16.6)
1		
2	299 (45.4)	313 (48.2)
3	247 (37.5)	185 (28.5)
4	26 (4.0)	41 (6.3)
5	1 (0.2)	1 (0.2)
Mode of surgery:		
Urgent or emergency	201 (30.5)	177 (27.3)
Elective or scheduled	457 (69.5)	472 (72.7)

Table 3| Intraoperative data collected for patients who had surgery before and after the implementation of fluid administration guided by oesophageal Doppler monitoring

Variable	Control (n=658)	Intervention (n=649)	P value*
Mean (SD) stroke volume (ml):			
Start of surgery	—	80.7 (27.7)	<0.001
End of surgery	—	97.2 (31.7)	
Mean (SD) intravenous fluid (ml):	3106.0 (1604.0)	3354.9 (1838)	0.09
Colloid	734.3 (752.0)	985.9 (776.1)	<0.001
Crystalloid	2183.1 (1003.4)	2196.2 (1165.5)	0.83
Plasma	44.7 (284.2)	34.1 (205.6)	0.44
Blood	136.1 (454.3)	135.1 (404.0)	0.97
Monitoring (%):			
Doppler inserted	74 (11.2)	429 (65.1)	<0.001
Central venous catheter	290 (44.1)	221 (34.1)	<0.001
Arterial line	274 (41.6)	281 (43.3)	0.58

*Independent samples *t* test used for fluid volumes; χ^2 test used for monitoring.

Table 4| Length of stay (days) before and after the implementation of fluid administration guided by oesophageal Doppler monitoring. P values calculated using an independent samples t test

	Control		Intervention		
Patient group	**No**	**Mean (SD) stay**	**No**	**Mean (SD) stay**	**P value**
Total	658	18.7 (24.4)	649	15.1 (16.7)	0.002
Derby	201	10.9 (10.7)	201	8.4 (7.3)	0.007
Manchester	232	25.5 (34.8)	224	19.8 (23.2)	0.043
Whittington	225	15.7 (13.4)	224	13.4 (12.7)	0.108
Post-operative	658	17.2 (24.0)	649	13.6 (15.9)	0.001
Intensive care					

Table 5| Number (percentage) of readmissions and reoperations after surgery in three hospitals before and after the implementation of fluid administration guided by oesophageal Doppler monitoring

Variable	Control (n=658)	Intervention (n=649)	P value (χ^2 test)
Readmission:			
To critical care	22 (3.3)	14 (2.2)	0.20
To hospital	36 (5.5)	25 (3.9)	0.20
Reoperation	55 (8.4)	38 (5.9)	0.08
In-hospital mortality	23 (3.5)	18 (2.8)	0.37

Figure

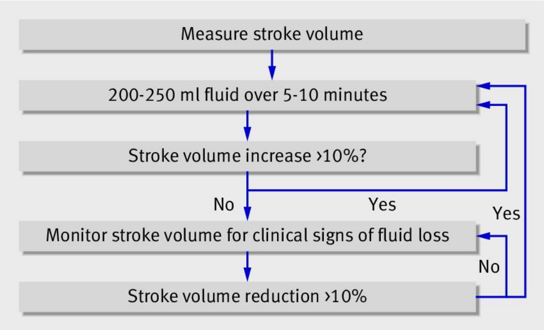

Fig 1 Intraoperative fluid management using stroke volume optimisation technique with oesophageal Doppler monitoring