

THE IMPACT OF SYSTEM FACTORS ON QUALITY AND SAFETY IN ARTERIAL SURGERY: A SYSTEMATIC REVIEW

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Key words: quality; safety; arterial surgery; system factors

What this study adds: This review addresses a topic that is poorly understood in vascular surgery: how system factors such as teamwork and the work environment influence quality and safety. The evidence appraised in this review indicates that there is likely to be an association between issues such as teamwork, organizational factors and the work environment, and patient outcomes – a relationship that warrants further investigation by the vascular community.

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ABSTRACT

Objective

A systems approach to patient safety proposes that a wide range of factors contribute to surgical outcome, yet the impact of the operating environment and of team and organizational factors, is not well understood in arterial surgery. The aim of this systematic review is to summarise and discuss what is already known about the impact of system factors on quality and safety in arterial surgery.

Data sources

A systematic review of original research papers in English using MEDLINE, Embase, PsycINFO and Cochrane databases, was performed according to PRISMA guidelines.

Review methods

Independent reviewers (RL and ADG) selected papers according to strict inclusion and exclusion criteria, and, using predefined data fields, they extracted relevant data on organizational, work environment, and team factors, and measures of quality or safety, in arterial procedures.

Results

Of eight studies meeting selection criteria, most (6/8) measured the relationship between team factors and quality or safety. Five studies evaluated organizational factors and three papers addressed the work environment. Significant improvements in outcome were reported in two of three papers that evaluated clinical pathways, though these studies were of variable quality. Two single-centre studies demonstrated that work environment issues, such as equipment failures, occur frequently during arterial operations, especially during those procedures with an endovascular component. Two further single-centre studies identified a trend towards fewer errors or procedural problems when more effective teamwork was observed, though whether such quality improvements actually translate into better patient outcomes remains to be investigated.

Conclusions

A small number of heterogenous, single-centre studies have evaluated the relationship between system factors and quality or safety in arterial surgery. Future research should include larger, multi-centre trials to validate this relationship, and to investigate whether improvements in teamwork and the work environment are associated with better patient outcomes.

INTRODUCTION

Of significant interest to the vascular community is variation in outcomes at national and institutional levels. A relationship between annual caseload volume and patient outcome is now well established for many arterial procedures. Robust evidence demonstrates that higher procedural volumes predict lower operative mortality for a range of arterial procedures including elective open abdominal aortic aneurysm (AAA) repair, endovascular aortic aneurysm repair (EVAR), carotid endarterectomy (CEA) and lower extremity bypass^{1–3}. Such evidence has prompted major service reconfiguration (centralization) in recent years.

Interestingly, individual surgeon volume does not account for the entire effect of institutional volume, with the relative importance of surgeon volume varying according to operation performed⁴. Therefore, other determinants within a healthcare institution must also play a role. Beyond patient co-morbidity and surgical technique, wider factors influencing quality and safety are poorly understood in arterial surgery.

A systems approach to surgical quality and safety proposes that all aspects of the healthcare system should be considered when attempting to explain outcome⁵. A number of studies conducted in the surgical setting have implicated communication failures, fatigue, poor staffing levels and equipment problems^{6–8}. This systematic review aims to summarise and discuss what is known about the impact of organizational, work environment and team factors on quality and safety in arterial surgery.

METHOD

Protocol

The protocol for this systematic review was specified in advance of the review taking place. The methodology and reporting of the review adheres to the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement (PRISMA)⁹.

Definitions

Quality and safety

Rates of mortality, complications or length of stay, were considered measures of quality and safety. Since hard outcomes such as mortality may be rare, certain process measures were also designated as markers of quality and safety. These included rates of errors or procedural problems, and operative duration.

Factors influencing surgical quality and safety

A systems approach was adopted for the purposes of this review to take evaluation of factors influencing surgical quality and safety beyond patient risk factors and surgical skill. This approach, which has been described in full elsewhere⁵ encourages consideration of all potentially relevant factors implicated in surgical quality and safety in the perioperative period. This review considers three overarching themes informed by a previously published framework of factors influencing clinical practice¹⁰: organization and management, work environment, and team factors. Further details of these themes are provided in table 1.

Elective arterial surgery

Elective arterial surgery refers to the planned open surgical or endovascular treatment of aneurysmal or occlusive arterial disease. The evaluation of factors influencing safety and quality in *emergency* surgery was deemed beyond the scope of this review.

- Table 1: Factors influencing surgical quality and safety -

Information sources

The following databases were systematically searched: Medline [Ovid Medline 1946 to 1st July 2016], Embase [Embase 1947 to 30th June 2016], PsycINFO [PsycINFO 1967 to June Week 5 2016], and the Cochrane Library. Reference lists of key papers were handsearched for additional citations. The last search was performed on 1st July 2016.

Search

A comprehensive list of search terms was devised in consultation with vascular and patient safety experts, identification of commonly used terms in the literature and synonyms of

relevant terms (appendix 1). It was anticipated that few papers would specifically focus on investigation of organizational, work environment or team factors, therefore, the search was deliberately broad to capture papers that may include an assessment of such factors as an aspect of a wider study. Search terms were categorized into three groups: arterial disease; surgical intervention; measures of quality and safety. Within groups, search terms were linked by the Boolean operator 'OR'. Each group of search terms was linked using the Boolean operator 'AND'. MeSH (Medical Subject Headings) were used to ensure that the search was comprehensive. Limits were applied for humans, abstracts and papers in the English language.

Study selection

The primary reviewer (RL, advanced vascular nurse practitioner) screened all titles and abstracts according to predefined inclusion and exclusion criteria, with a second reviewer (ADG, clinical research fellow) screening ten percent of citations. Cohen's kappa demonstrated good agreement between reviewers ($\kappa = .86$, $p < .001$). Both reviewers screened all papers selected for full text review to select included papers ($\kappa = .78$, $p < .001$). Any disagreements between reviewers at each stage of selection were resolved by consensus.

Inclusion criteria

Studies were eligible for inclusion if they were original research papers published in a peer-reviewed journal, which addressed the relationship between organizational, work environment or team factors and quality or safety measures in elective arterial surgery during the perioperative period. Original research papers investigating interventions to optimize organizational, work environment or team factors using safety or quality measures were also included.

Exclusion criteria

Studies investigating the impact of patient risk factors, surgical techniques, or pharmacological interventions (e.g. cardioprotective medication) were excluded. Studies solely describing the following operation types were also excluded: emergency arterial surgery; iatrogenic arterial injury; the vasculature of the heart or the brain; type A aortic dissection; arterial closure devices.

The search returned many papers examining the relationship between hospital or surgeon volume and patient outcomes, and clinical pathways in arterial surgery. Volume outcome relationships have already been examined exhaustively in arterial surgery (refs), and such studies are therefore excluded from this review. Only clinical pathway papers published

within the last decade were considered to be relevant to the current state of arterial service provision; clinical pathway papers published earlier than 2005 were therefore excluded. Reviews, case reports, editorials, opinions and conference proceedings were excluded.

- Figure 1: PRISMA diagram for study selection -

Data collection process and data items

For each paper, details of the design, aim, study period, sample size, type of surgical intervention, aspect of organizational, work environment or team factor investigated, and measure(s) of quality or safety used, and details of intervention if applicable, were extracted using a standardized data extraction form. The primary reviewer (RL) extracted all preset information, which was subsequently checked and verified by the second reviewer (ADG).

Risk of bias of individual studies

Case-control studies were quality assessed using the Newcastle-Ottawa Scale, which has been described in full elsewhere¹¹. A modified version of the Newcastle-Ottawa Scale¹² was used to assess the quality of cross-sectional studies. Studies were assessed for risk of bias, based on case selection, comparability of groups and outcome measurement and analysis. High quality case-control and cross-sectional studies attained the maximum score of 9; medium quality studies obtained a score of 7 or 8, while a score of 6 or less indicated that the study was of poor quality (tables 2 & 3). Two reviewers (RL and ADG) independently scored case-control and cross-sectional papers, with satisfactory agreement between assessors for quality scoring ($\kappa = .56$, $p=.01$). Due to the small number of papers retrieved from the search, low quality papers were included in the review. The only randomized controlled trial (RCT) identified through the search strategy, was appraised using the Cochrane Collaboration's tool for assessment of risk of bias¹³. A critical appraisal of all included studies, guided by the STROBE checklist¹⁴ (Strengthening the Reporting of Observational studies in Epidemiology) has been included in tables 2 and 3 to make explicit particular strengths and weakness that may influence the findings.

- Table 2: Quality assessments for one case-control and

four cross-sectional studies using the (modified) Newcastle-Ottawa Scale -

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- Table 3: Quality assessments for two descriptive studies and one randomized controlled trial -

RESULTS

Study characteristics

Eight studies^{15–22} met selection criteria (PRISMA diagram, figure 1). Six of these were undertaken in the United Kingdom (UK)^{15, 17, 18, 20–22}. There were two descriptive studies^{15, 22}, one case-control²¹ and four cross-sectional studies^{16–18, 20}, and one randomized control trial (RCT)¹⁹. Five studies measured the impact of an *intervention* designed to improve surgical quality and safety^{16, 17, 19–21}. The most common operation studied was aortic aneurysm (AAA) repair (6/8 studies^{15–17, 19–21}), though only three of these included *endovascular* aortic aneurysm repairs (EVARs)^{15, 17, 21} and only one paper studied complex combined open and endovascular procedures²¹. Four papers addressed carotid endarterectomy (CEA)^{15, 17, 18, 22} and three papers included lower limb bypass graft (LL BG)^{15, 17, 22}. Five papers addressed organizational factors^{15–17, 19, 20}, three papers addressed work environment factors^{15, 16, 21} and six papers addressed team factors^{15–18, 21, 22}. Four papers measured patient outcomes^{16, 17, 19, 20} and five papers measured surrogate markers of surgical quality and safety (including intraoperative errors or procedural problems, and operating time)^{15, 18, 21, 22}.

Quality Assessment

Seven of eight papers reported single-centre studies^{15, 17–22}, and of these, two had sample sizes of less than 20 cases^{21, 22}. However, one cross-sectional study included 658 hospitals across the United States (US) with a large sample size of 16,732 survey respondents¹⁶. Only one of the studies was a randomized controlled trial¹⁹, which reported outcomes on an intention-to-treat basis, but researchers and patients could not be blinded to the allocation groups due to the nature of the intervention studied. Of the case-control and cross-sectional studies scored using the Newcastle-Ottawa Scale, only one paper was scored as high quality¹⁶ and three papers were deemed to be of low quality^{17, 18, 20}. Details of the quality assessments for all papers are provided in tables 2 and 3.

Factors influencing quality and safety in arterial surgery

Relevant findings from included papers are organized into the following three themes: organizational, work environment and team factors. Table 4 provides a summary of these study characteristics.

Organisational Factors

Three studies examining the impact of a clinical pathway intervention were reviewed: one pre-operative¹⁷, and two post-operative^{19, 20}, interventions. Clinical pathways are complex interventions that require changes in the structure of an organization to optimize allocation of resources and improve patient care. Clinical pathways define the sequencing and timing of health interventions²³.

Cantlay et al., describe their experiences of introducing a pre-operative assessment clinic (PAC) led by vascular consultant anaesthetists, designed to evaluate and manage pre-operative risk for patients undergoing major vascular procedures¹⁷. While patients scheduled for a variety of arterial operations were reported to have attended the clinic, the authors report unadjusted mortality rates pre- and post-intervention for open infrarenal aneurysm repair only (14.5% and 4.8%, respectively). Patient risk factors and other confounding variables were not accounted for. Of note, introduction of the PAC took place at the same time as centralization of arterial services within this organization.

Two further studies evaluated clinical pathway interventions in the post-operative period. In a single-centre randomized controlled trial, Muehling et al. piloted the safety and efficacy of a fast-track recovery pathway for patients undergoing open AAA repair, which included reduced preoperative fasting, no bowel preparation, patient-controlled epidural anaesthesia, enhanced post-operative feeding and early mobilization¹⁹. Patient characteristics, surgical procedure and clamping time were comparable between the two groups ($p > 0.05$ for all characteristics). In this RCT, which assessed outcomes on an intention-to-treat basis with a low attrition rate (5 of 101 patients excluded), the rate of post-operative medical complications was significantly lower (16% versus 36%; $p = .039$), and length of stay was significantly shorter (10 days versus 11 days; $p = .016$) in patients entered into the fast-track program compared to the treatment group. In a similar study of a fast-track, goal directed clinical pathway for elective open AAA repair, Murphy et al., demonstrated shorter length of stay following implementation of the pathway (from median of 9 days (range 4-17) to 5 days (range 2-12), $p < .001$)²⁰. The authors explained that this reduction in length of stay was achieved by standardizing the time frames in which established practices are undertaken. However, this was a cross-sectional study using historical controls, and though the two groups appeared similar in terms of patient demographics, these characteristics were not subject to statistical enquiry.

A large, multi-centre cross-sectional study investigated US healthcare organizations' adherence to 27 hospital safety measures comprising a comprehensive set of evidenced-based hospital process measures and standardized practices endorsed by the National Quality Forum

(NQF)¹⁶. Interestingly, the risk-adjusted mortality benefit conferred by full compliance with NQF safety practices was significant for most high-risk procedures but not for open AAA repair (Odds Ratio, 0.85; 95% CI, 0.71-1.03), a finding that the authors do not comment on in their discussion. Of note, the level of compliance with NQF safety practices was calculated from self-report data and the survey had a 50% response rate.

Work Environment Factors

The NQF safety practices evaluated in Brooke et al's study of the relationship between compliance and post-operative outcomes include standards ensuring safe nursing staffing levels and workspaces where medications are prepared free from clutter, distraction and noise¹⁶. However, the findings are not presented in sufficient depth to ascertain the relative impact of compliance with individual standards. Such granular detail was presented in Albayati's observational study of intraoperative failures¹⁵. Failures relating to equipment (unavailability, configuration, workspace/equipment management, malfunction) were the most frequently observed intraoperative failure (23.5%, n=269/1145 failures) in this study of AAA repair, CEA and LL BG. Equipment and workspace failures constituted 13% (n=8/59) of all major failures that delayed the procedures or endangered the patient. Examples given were imaging equipment malfunction and stent graft deployment failure due to snapping of deployment mechanism. However, this study did not investigate the relationship between intraoperative failures and patient outcomes. A further study at the same institution evaluated an intervention designed to improve efficiency of equipment-use during complex aortic aneurysm repairs that involve both open and endovascular components²¹. In this small pilot study of 15 cases, Patel and colleagues implemented a structured, mental rehearsal before the endovascular phase and evaluated its impact on the number and severity of intraoperative errors. In six operations post-intervention, error rates were reduced during the endovascular phase (7.64 errors/hour (1.71-9.6) pre-intervention vs. 3.75/hr (1.71-5.54 post-intervention), p=0.05), and measures of intraoperative delay and threats to patient safety were also reduced.

Team Factors

Patel's and colleagues' structured mental rehearsal intervention not only aimed to improve intraoperative efficiency in equipment use, it was also designed to improve team dynamics though prompting team discussion of procedural steps²¹. The authors reported a trend towards lower rates of communication and planning errors post-intervention (0.86 errors/hr (0-2.73) vs. 0/hr (0-0.92), p=0.084, and 0.6/hr (0-2.67) vs. 0/hr (0-2.0), p=0.141). These non-significant findings may be explained by the small sample size of this pilot study, which did

not address the relationship between intraoperative errors and patient outcomes. In Albayati et al.'s observational study, a significant proportion of intraoperative failures were communication problems (21%, 240/1145)¹⁵. Examples provided include miscommunication between anaesthetic and surgical teams during balloon occlusion of the aorta and heparin not being administered despite a request. Communication errors relating to heparin administration during arterial procedures were also described in Catchpole et al.'s study of teamwork and error in the operating room¹⁸. This single-centre study used a validated assessment tool to measure four aspect of team factors: leadership and management; teamwork and cooperation; problem solving and decision-making; and situational awareness, as well as a direct observational methodology to capture errors and procedural problems during 22 carotid endarterectomies. An example of a failure in communication and coordination and lack of supervision was described by the authors: the surgeon requested heparin to be given to reduce the risk of emboli at the site of the arterial cross-clamp, but the consultant anaesthetist was absent at the time. The anaesthetic registrar mistakenly administered normal saline instead of heparin. The error was rectified when the consultant anaesthetist returned, and the operation continued without harm to the patient. This study found that, for carotid endarterectomy, an anaesthetist's leadership and management score of 5 (indicating exceptional teamwork behavior) was associated with an operative duration that was 19 minutes longer than when the anaesthetist had an equivalent score of 3 (indicating teamwork behaviors that may compromise patient safety) ($p<0.001$), implying the need for a compromise between speed and safety. Surgeons' situational awareness scores had a strong negative correlation with the rate of errors in surgical technique ($p<0.001$).

A descriptive study by Soane and colleagues also evaluated relationships between team factors and intraoperative errors in CEA²². Unlike the study by Catchpole and colleagues, which used regression models to determine whether differences in operative duration and error rates were associated with team factors, this single-centre, observational pilot study aimed to identify trends in teamworking and error patterns. Soane and colleagues demonstrated that error rates (per hour) were lower when effective pre-briefing took place (4.50 vs. 5.39 errors/hr), when communications were kept to a practical minimum (4.64 vs. 5.56 errors/hr) and when the progress of surgery was communicated throughout (3.134 vs. 8.33 errors/hr). Teamwork processes in this study were assessed using self-report methods and trends were not subject to statistical enquiry due to the small sample size.

- Table 4: Characteristics of Included Studies -

DISCUSSION

This is the first systematic review to adopt a systems approach to understanding quality and safety in arterial surgery. Organizational, work environment and team factors were evaluated with respect to patient outcomes and other markers of surgical quality and safety. The following key findings emerged from this review:

1. There appears to be a relationship between aspects of team performance during arterial operations and intraoperative errors or failures, but whether these failures translate into poorer outcomes remains to be studied.
2. Equipment failures appear to be a primary source of inefficiency and risk to patients intraoperatively. The impact of other aspects of the work environment remains unclear.
3. There is some evidence that clinical pathways positively influence patient outcomes for AAA repair, though either the standardization of timeframes for existing practices, or through the introduction of complex interventions (such as an anaesthetic pre-assessment clinic), but further RCTs would be beneficial in validating these findings.

Although available literature on system factors in arterial surgery was limited, this review summarizes deficiencies in the system that are immediately informative. Failures relating to team factors were consistently associated with high rates of intraoperative errors and procedural problems. This is concerning because arterial procedures are high-risk operations which demand precise communication and coordination between team members to ensure haemodynamic stability, particularly during critical phases of operations such as clamping and unclamping of major vessels, or stent deployment during EVAR. Small studies of team factors in arterial surgery have not linked associated errors with patient outcomes, but in other surgical specialties, failures in communication and information transfer have been directly associated with patient harm⁷. In the UK, current training programmes in vascular surgery do not routinely include training in non-technical skills, though individual studies on the use of simulation to improve team performance in arterial operations are encouraging²⁴.

Deficiencies relating to equipment used during arterial procedures appear to be a central cause of inefficiency and risk to patients, particularly during endovascular procedures. This finding is perhaps not surprising given the rapid uptake and evolution of endovascular technology to treat patients with arterial disease. Cardiac surgery, which also relies heavily on technology, has been shown to bear a greater burden of equipment-related errors compared to general surgery⁸. While endovascular aneurysm repair (EVAR) is associated with reduced procedural mortality and equivalent longer-term mortality compared with open repair²⁵, experience with this technology is likely to reduce intraoperative error rates, which may further enhance patient outcomes. Centralization of services should facilitate safe use of

minimally-invasive technologies, but at an institutional level, Patel and colleagues' structured, mental rehearsal appeared to be successful in reducing equipment-related error during the endovascular phase of hybrid aortic procedures²¹; larger multi-centre studies are needed to evaluate this fully.

This review found some evidence that the structure of hospital organizations and the sequencing and timing of care is important in determining patient outcomes. There was limited evidence that length of stay may be safely reduced for patient undergoing AAA repair, without compromising patient safety. The implementation of a clinical pathway requires organizational support and can be resource-intensive, and thus, both the benefits and costs should be considered prior to implementation²³. Unfortunately, none of the three studies addressing clinical pathways in this review provided details of cost analyses, and it is therefore difficult to fully assess the merits of each pathway described.

This review clearly shows that there is a lack of research studies that adopt a systems approach to explaining patient outcomes in arterial surgery. Many aspects of the work environment that conceivably influence surgical quality and safety have yet to be studied. For example, a recent evaluation of the vascular workforce revealed that the majority of vascular consultants in the UK work more than 50 hours a week, with many working to provide emergency cover more frequently than is considered safe²⁶ but the impact of working long hours on service quality and patient outcome is not known. The design and methodologies of the studies in this review are not consistent. This heterogeneity makes it challenging to draw meaningful conclusions. Research in this field would benefit from collaborative efforts between institutions with use of validated assessment methods and consistent endpoints. Large randomized controlled trials could improve generalizability and power to predict associations between interventions to improve quality and safety, and patient outcomes.

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- Table 1: Factors influencing surgical quality and safety -

Organization and management factors	Work environment factors	Team factors
Financial resources & constraints Organizational structure Policy standards & goals Safety culture & priorities	Staffing levels & skill mix Workload & shift patterns Availability & maintenance of equipment Administrative & managerial support	Verbal communication Written communication Supervision & seeking help Team structure (consistency, leadership etc)

Table 2: Quality assessments for one case-control and four cross-sectional studies using the (modified) Newcastle-Ottawa Scale

First Author Year	Study setting	Sample size	Study design	Selection (max 5 stars)	Comparability (max 2 stars)	Outcome (max 3 stars)	Overall quality score	Critical appraisal of factors likely to influence interpretation of findings
Brooke 2012	658 nationwide hospitals, US	16,732	Cross-sectional	****	**	***	High (9)	Multi-centre study with large sample size. Patient- & hospital-level variables controlled for in regression model. Self-report method, 50% response rate
Cantlay 2006	Single centre regional vascular unit, UK	234	Cross-sectional	****	0	0	Low (4)	Single-centre study. Comparison of mortality rates pre- & post-intervention provided for AAA repairs only. Patient risk factors/other confounders not controlled for.
Catchpole 2008	Single centre regional vascular unit, UK	22	Cross-sectional	***	*	**	Low (6)	Small sample size. Single-centre study. Tools used to evaluate teamwork & surgical errors were previously validated.
Murphy 2007	Single centre regional vascular unit, UK	60	Cross-sectional	***	0	***	Low (6)	Single-centre study. Demographics briefly described for each group though not controlled for with statistical methods.
Patel 2012	Single centre regional vascular unit, UK	15	Case-control	****	0	***	Medium (7)	Small sample size. Single-centre study. Descriptions of demographics for each group not sufficiently detailed to judge comparability. Observer & assessors not blinded to whether case was pre- or post-intervention.

Selection assesses representativeness of the sample, sample size, description of cases not included, and measurement of the exposure. Comparability assesses the extent to which confounding factors are controlled for to ensure different outcome groups are comparable. Outcome assesses the quality of outcome assessment and statistical analyses.

Table 3: Quality assessments for two descriptive studies and one randomized controlled trial

First Author Year	Study setting	Sample size	Study design	Critical appraisal of factors likely to influence interpretation of findings
Albayati 2012	Single centre regional vascular unit, UK	66	Descriptive	Single-centre study. Observational method: unstructured observations undertaken by medical students. Two blinded assessors with significant vascular surgical experience judged intraoperative failures. Non-significant correlations between patient age & ASA grade, & failure rate (as potential confounders) are described.
Soane 2014	Single centre regional vascular unit, UK	12	Descriptive pilot study	Small sample size. Single-centre study. Observational method to capture intraoperative errors: previously validated, structured approach with independent verification by two vascular surgical experts. Self-report method to evaluate the role of teamworking. Attempts made to reduce Hawthorne effect prior to study. Data analysed to examine trends – statistical analysis not performed due to small sample size.
Muehling 2009	Single centre, Germany	101	Randomized controlled trial [^]	Single-centre study <i>Selection bias</i> : patients were randomly assigned to either the traditional or the fast-track treatment arm but further description of allocation not provided. <i>Performance & detection bias</i> : blinding not feasible due to nature of intervention. <i>Attrition bias</i> : Intention-to-treat analysis performed. Five excluded (2 withdrew consent, 2 suprarenal clamping, 1 EDA dysfunction) Attrition not expected to affect results. <i>Reporting bias</i> : All pre-specified outcomes were reported.

Quality of the RCT was assessed using the Cochrane Collaboration's tool for assessment risk of bias in randomized trials

Table 4: Characteristics of Included Studies

First Author Year	Operation type(s)	Intervention	Organizational Factors assessed	Work Environment Factors assessed	Team Factors assessed	Measures of quality & safety assessed	Findings
Albayati 2012	TAAA repair AAA repair (open & endovascular) CEA LL BG	N/A	1. External resource failures 2. External pressures	1. Team member absence 2. Equipment unavailability/ configuration/ malfunction 3. Fatigue	1. Communication 2. Team conflict	Intra-operative failure distribution	Most frequent failures related to equipment or communication. Failures were significantly higher in the endovascular phase.
Brooke 2012	Open AAA repair	Implementation of National Quality Forum (NQF) safety practices	1. Creation of safety culture 2. Pharmacy involvement with medication-use process 3. Specialist anti-coagulation service involvement 4. Protocols for prevention of complications	1. Nursing staffing levels 2. Workspaces where medications are prepared free from clutter, distraction, noise	1. Communication –standardized practices for written documentation including prescriptions & labelling of radiographs	In-hospital complications Failure to rescue (FTR) All-cause 30-day mortality	Hospitals that fully implemented safe practices were more likely to diagnose complications, had lower FTR rates, and had lower in-hospital mortality rates for most high-risk procedures, but not for AAA repair, compared to hospitals with partial safe practice compliance.

Table 4 continued:

First Author Year	Operation type(s)	Intervention	Organizational Factors assessed	Work Environment Factors assessed	Team Factors assessed	Measures of quality & safety assessed	Findings
Cantlay 2006	AAA repair-open & EVAR LL BG CEA	Implementation of vascular consultant anaesthetist-led pre-operative assessment clinic (PAC)	1. Change in patient pathway (pre-operative)		1. Multi-disciplinary referrals	In-hospital mortality	In-hospital mortality for AAA repair fell from 14.5% in 2-year period before PAC to 4.8% in 2 years after introduction of PAC. Improvement likely multi-factorial but implementation of PAC played major role.
Catchpole 2008	CEA	N/A			1. leadership & management 2. teamwork & cooperation 3. problem solving & decision-making 4. situational awareness	Operating time Errors in surgical technique Other procedural problems	Aspects of team performance strongly correlated with errors & procedural problems. Teamwork interventions could improve technical performance and patient outcomes.
Muehling 2009	Open AAA repair	Implementation of fast-track recovery program	1. Change in patient pathway (post-operative)			Morbidity & mortality Length of stay	Postoperative complications and hospital stay significantly reduced in fast-track group compared traditional treatment group.
Murphy 2007	Open AAA repair	Implementation of fast-track goal-directed pathway	1. Change in patient pathway (post-operative)			Length of stay	Median hospital stay reduced from 9 to 5 days following implementation of the pathway.

TAAA: thoraco-abdominal aortic aneurysm, AAA: abdominal aortic aneurysm, CEA: carotid endarterectomy, LL BG: lower limb bypass graft

Table 4 continued:

First Author Year	Operation type(s)	Intervention	Organizational Factors assessed	Work Environment Factors assessed	Team Factors assessed	Measures of quality & safety assessed	Findings
Patel 2012	Combined open & endovascular TAAA & AAA procedures	Implementation of a structured, mental rehearsal before the endovascular phase		1. Intervention designed to increase efficiency in equipment use	1. Intervention designed to improve team dynamics	Intraoperative error rates Delay scores Danger scores	Errors rates were significantly higher during the endovascular phase compared to open. Error rates, danger & delay scores were significantly lower after the intervention.
Soane 2014	CEA LL BG	N/A			1. team orientation 2. coordination & leadership style 3. communication 4. error management 5. task distribution	Intraoperative error rates	Error rates were lower when there were effective teamwork measures in place. Teamwork training for vascular teams may help to prevent or mitigate errors.

TAAA: thoraco-abdominal aortic aneurysm, AAA: abdominal aortic aneurysm, CEA: carotid endarterectomy, LL BG: lower limb bypass graft

Appendix: Search terms for Medline, Embase and PsycINFO

1. (adverse adj2 event\$).ab,ti.
2. Postoperative Complications/ep, mo [Epidemiology, Mortality]
3. patient safety indicator\$.ab,ti.
4. harm.ab,ti.
5. error\$.ab,ti.
6. morbidity/ or incidence/ or prevalence/ or mortality/ or "cause of death"/ or fatal outcome/ or hospital mortality/ or survival rate/
7. frequency.ab,ti.
8. rate.ab,ti.
9. severity.ab,ti.
10. Treatment Outcome/
11. consequence\$.ab,ti.
12. avoidable.ab,ti.
13. prevent\$.ab,ti.
14. operation.ab,ti.
15. intervention\$.ab,ti.
16. surg\$.ab,ti.
17. Arterial Occlusive Diseases/ or Peripheral Arterial Disease/
18. Vascular Surgical Procedures/ or vascular surgery.mp.
19. endovascular.ab,ti.
20. bypass.ab,ti.
21. aort\$.ab,ti.
22. carotid.ab,ti.
23. Aortic Aneurysm, Abdominal/ or Aneurysm, Dissecting/ or Aneurysm, Ruptured/ or Aortic Aneurysm, Thoracic/ or Iliac Aneurysm/ or Aortic Aneurysm/
24. Limb Salvage/ae, mo [Adverse Effects, Mortality]
25. 1 or 2 or 3 or 4 or 5
26. 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
27. 14 or 15 or 16
28. 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24
29. 25 and 26 and 27 and 28
30. "gastric bypass".ab,ti.
31. "cardiopulmonary bypass".ab,ti.
32. "heart bypass".ab,ti.
33. "coronary artery bypass".ab,ti.
34. "coronary bypass".ab,ti.
35. "coronary intervention".ab,ti.
36. "aortic valve".ab,ti.
37. "coronary artery stenting".ab,ti.
38. (cerebral adj3 aneurysm).ab,ti.
39. 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38
40. 29 not 39
41. limit 40 to abstracts
42. limit 41 to humans
43. limit 42 to english language