Is there a positive volume-outcome relationship in peripheral vascular surgery: results of a systematic review
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Authors' objectives
To examine the evidence for the existence, or otherwise, of a positive volume-outcome relationship in the area of peripheral vascular surgery.

Searching
MEDLINE, EMBASE, the Science Citation Index, HealthSTAR, DHSS Data, HELMIS and the Cochrane Library were searched from 1986 to 1998 using the following keywords: 'vascular surgery utilization', 'endarterectomy utilization', 'high volume', 'low volume', 'peripheral vascular utilization', physicians practice patterns', 'carotid artery diseases', 'carotid arteries', 'peripheral vascular disease', 'health services misuse', 'utilization review' and 'vascular surgery'. Only papers published in English in peer-reviewed journals were included. Editorials, letters and abstracts were excluded. The authors also identified relevant citations from retrieved articles.

Study selection
Study designs of evaluations included in the review
Prospective or retrospective volume-outcome studies.

Specific interventions included in the review
Studies had to address the issue of volume in peripheral vascular surgery. Specific interventions were annual caseloads, i.e. low- versus high-volume, at the hospital and physician levels.

For studies of carotid endarterectomy in hospitals, low-volume annual caseloads ranged from 1 to less than or equal to 100, and high-volume ranged from at least 15 to greater than 100. For physicians, low-volume caseloads ranged from less than 1 to less than 15, whilst high-volume ranged from greater than to greater than 50.

For studies of abdominal aortic aneurysm repair in hospitals, low- volume caseloads ranged from 1 to less than 50, whilst high-volume ranged from greater than 10 to at least 50. For physicians, low-volume caseloads ranged from 1 to 5, whilst high-volume ranged from greater than 2 to greater than 26. For studies of 'other vascular interventions', volume annual caseloads were defined for only one study.

Participants included in the review
The participants underwent one of the following procedures: carotid endarterectomy, abdominal aortic aneurysm repair, or 'other vascular interventions'.

Outcomes assessed in the review
The studies had to assess the following outcomes: post-operative mortality and/or stroke rates, or combined mortality and stroke rates, for studies of carotid endarterectomy; post-operative mortality for studies of abdominal aortic aneurysm repair, with results presented separately for ruptured and/or unruptured aneurysms; and mortality starting at 30 days, amputation rates or morbidity for studies concerning 'other vascular interventions'.

How were decisions on the relevance of primary studies made?
Two authors independently read abstracts and performed the study selection based on pre-defined inclusion and exclusion criteria. Any disagreements were resolved by a third author.

Assessment of study quality
The authors assessed the validity of papers by classifying them into three categories: those that made no adjustment for case-mix, i.e. no account was taken of the diversity of participant characteristics that these samples may contain; partial
adjustment for case-mix, i.e. papers that adjusted for demographics and co-morbidity but did not adjust for severity or stage of illness; and full adjustment for case-mix, i.e. papers that made adjustments for demographic factors, co-morbidity and severity or stage of illness. The criteria were applied and agreed by consensus between two authors. Where discrepancies arose, decisions were referred to a third author for arbitration.

Data extraction
Two authors independently categorised the studies. Where discrepancies arose, decisions were referred to a third author for arbitration.

Studies were classified by intervention type (endarterectomy, abdominal aortic aneurysm repair and 'other vascular interventions') and level of adjustment (none, partial and full). Data were extracted for the categories of: study identification, number of patients or procedures performed, annual caseload by hospital and physician, and statistical results.

Methods of synthesis
How were the studies combined?
A narrative synthesis of the results was presented.

How were differences between studies investigated?
In the narrative summary, papers were classified and discussed according to the level of adjustment for case-mix.

Results of the review
Thirty-six papers were included in the review: 17 concerned carotid endarterectomy, 16 concerned abdominal aortic aneurysm repair, and 4 concerned 'other vascular interventions' such as reconstructive surgery and amputation. One of the papers concerned both carotid endarterectomy and abdominal aortic aneurysm repair.

For studies concerning carotid endarterectomy, sample sizes ranged from 364 to 113,300 participants, whilst for studies of abdominal aortic aneurysm repair, sample sizes ranged from 243 to 42,457 participants. The sample sizes were not reported for studies of 'other vascular interventions'.

The findings for carotid endarterectomy identified a positive volume-outcome relationship for both mortality and stroke at the physician level. There was less support for a positive relationship for mortality at the hospital level, and no evidence of benefits for stroke in higher volume hospitals. However, the evidence was inconclusive if only those studies making a full adjustment for case-mix were included; there was no clear support either for or against a positive volume-outcome relationship.

For repair of unruptured abdominal aortic aneurysms there was evidence of a positive volume-outcome relationship at the hospital level, while for physicians the evidence was more balanced with no clear support either way. For 'other vascular interventions' there were insufficient studies (n=4) from which to draw meaningful conclusions.

Authors' conclusions
The results show that evidence of a relationship between volume and outcome in peripheral vascular surgery may be attributable to factors such as lack of adjustment for case-mix, different definitions of volume, and poor quality of studies, especially those of retrospective design. Future studies should address these deficiencies by making full adjustment for case-mix and by adopting a prospective design.

CRD commentary
The inclusion criteria were clear but the exclusion criteria were limited to publication parameters, i.e. full article published in English in a peer-reviewed journal, rather than study characteristics. An attempt was made to search for all the relevant research literature, although only English language publications were retrieved and the review did not
consider unpublished research. The results may, therefore, be subject to publication bias.

A limited form of quality assessment was considered by categorising the studies according to one main assessment criteria, namely adjustment for case-mix.

Two reviewers independently assessed the inclusion and exclusion criteria and categorised the data. Any disagreements were referred to a third author. Relevant details of the individual studies were presented in the tables and text in appropriate categories.

The authors discussed the sources of heterogeneity, including the use of different volume cut-off points, and potential confounding factors, such as the experience of surgeons for aortic aneurysm repair. The authors did not, however, discuss the relevance of sample size in relation to the different volume cut-off points employed in each study. The authors' conclusions appear to follow from the results.

**Implications of the review for practice and research**
Practice: The authors did not state any implications for practice.

Research: The authors state that there is a need for more prospective studies to investigate volume-outcome relationships.

**Funding**
Department of Health.

**Bibliographic details**

**PubMedID**
11035964

**DOI**
10.1053/ejvs.2000.1188

**Indexing Status**
Subject indexing assigned by NLM

**MeSH**
Aortic Aneurysm, Abdominal /mortality /surgery; Endarterectomy, Carotid /methods /mortality /statistics & numerical data; Female; Humans; Male; Peripheral Vascular Diseases /mortality /surgery; Sensitivity and Specificity; Survival Analysis; Treatment Outcome; Vascular Surgical Procedures /methods /mortality /statistics & numerical data

**AccessionNumber**
1200002209

**Date bibliographic record published**
31/03/2002

**Date abstract record published**
31/03/2002

**Record Status**
This is a critical abstract of a systematic review that meets the criteria for inclusion on DARE. Each critical abstract
contains a brief summary of the review methods, results and conclusions followed by a detailed critical assessment on the reliability of the review and the conclusions drawn.