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REVIEW ARTICLE

Should tourniquets be used in upper limb surgery ? A systematic review and meta-analysis

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This study compares the intra- and post-operative outcomes of upper limb orthopaedic surgical procedures performed with and without tourniquet assistance. A systematic review was undertaken assessing the electronic databases Medline, CINAHL, AMED and EMBASE. The evidence-base was critically appraised using the Cochrane Bone, Joint and Muscle Trauma Group quality assessment tool. Study heterogeneity was statistically tested using Chi^2 and I^2 statistics. Where appropriate a random-effects meta-analysis was undertaken to pool results of primary studies assessing mean difference of each outcome. Two studies investigating fifty-five patients undergoing upper limb surgery were identified. The limited findings suggest that the use of tourniquets may reduce the incidence of technical difficulties during upper limb surgery. It remains unclear whether the application of a tourniquet can influence pain perception or operative duration. The evidence-base was considerably limited in both size and methodological quality. Further study is recommended to address the literature's methodological weaknesses.

Keywords : tourniquet ; upper limb ; hand ; forearm ; orthopaedic surgery.

INTRODUCTION

Tourniquets are frequently used during orthopaedic surgery to theoretically optimise visibility in a bloodless field, limit operative time and improve technical precision (*11,13,20,28,34,35*). However, the use of tourniquets has been associated with complications. These have included neurapraxia (*26,30*), vascular injury (*3,19*), post-operative swelling and joint stiffness (*1,22,31*), hyperaemia on tourniquet deflation and increased post-operative pain (*1,2,12,14,32*). The use of a tourniquet, particularly in lower limb surgery, can also cause a fluctuation in cardiovascular activity, with subsequent intra-operative cardiac arrest (*1,21,25,29,31*).

There is still debate as to whether tourniquets should routinely be used during upper limb surgery. The purpose of this study was to assess the intra- and post-operative outcomes of upper limb surgery with, compared to without, the application of a tourniquet.

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METHODOLOGY

Search strategy

This literature search was part of a larger study assessing the application of tourniquets in orthopaedic surgery. Accordingly, an electronic database search was performed using : Medline (1950 to December 2008), CINAHL (1982 to December 2008), AMED (1985 to December 2008) and EMBASE (1974 to December 2008), searched via Ovid using the MeSH terms and Boolean operators : tourniquet AND arm OR leg. In addition, the Cochrane library was searched using the term 'tourniquet'. The databases SIGLE (System for Information on Grey Literature in Europe), the National Technical Information Service, the National Research Register (UK), UKCRN Portfolio Database, and Current Controlled Trials database were used to identify unpublished or grey literature. Reference lists from any review papers and all obtained full-text articles, were scrutinised for additional articles not initially identified. Corresponding authors for each included paper were sent a list of all included citations, and were asked to comment whether they knew of any unidentified publications. The following inclusion and exclusion criteria were used :

Inclusion criteria

- All full text randomised and non-randomised controlled trials, comparing the clinical outcomes of upper limb surgery using and not using a tourniquet.
- Participants aged 16 years or older.
- Males and females.
- Published and unpublished material of any language, to include university theses and dissertations and conference proceedings.

Exclusion criteria

- Case reports of less than 5 subjects, comments, letters, editorials, protocols and guidelines.
- Animal or cadaveric studies.

Citation selection

Two reviewers (CH, TS) independently assessed the titles and abstracts of each citation identified by the search. Full-texts were ordered of those articles which appeared potentially eligible. These were then evaluated against the eligibility criteria. Those fully satisfying the criteria were included. Disagreements between reviewers were resolved through discussion.

Data extraction

Each reviewer (CH, TS) extracted data from the included papers. This was collectively tabulated to provide a consensus database. All articles were anonymised for author name, institution, journal title and year of publication. This blinded the reviewers during data extraction, appraisal and analysis.

Data analysis

The mean difference (MD) in clinical measures was compared for patients who had elbow, forearm, wrist or hand surgery with or without a tourniquet. The primary outcome measure was visualisation of the surgical field. Secondary outcomes measures were pain assessment, operative time, joint range of motion, muscle strength and complications including neurological impairment and wound healing disorders.

Since only two publications were identified, we descriptively assessed the different outcomes of each of these articles. Heterogeneity in results across studies was statistically tested and measured using I^2 and Chi^2 statistics. I^2 is a statistical test used to assess the heterogeneity or consistency of results between studies included in a meta-analysis. It describes the percentage of total variation across the studies, which is due to heterogeneity rather than to chance (*17*). Using this result, 0% indicates no observed heterogeneity, whilst larger values show increasing heterogeneity. Since heterogeneity was identified between samples, a random-effects meta-analysis model was used to pool results of the primary studies, when judged appropriate.

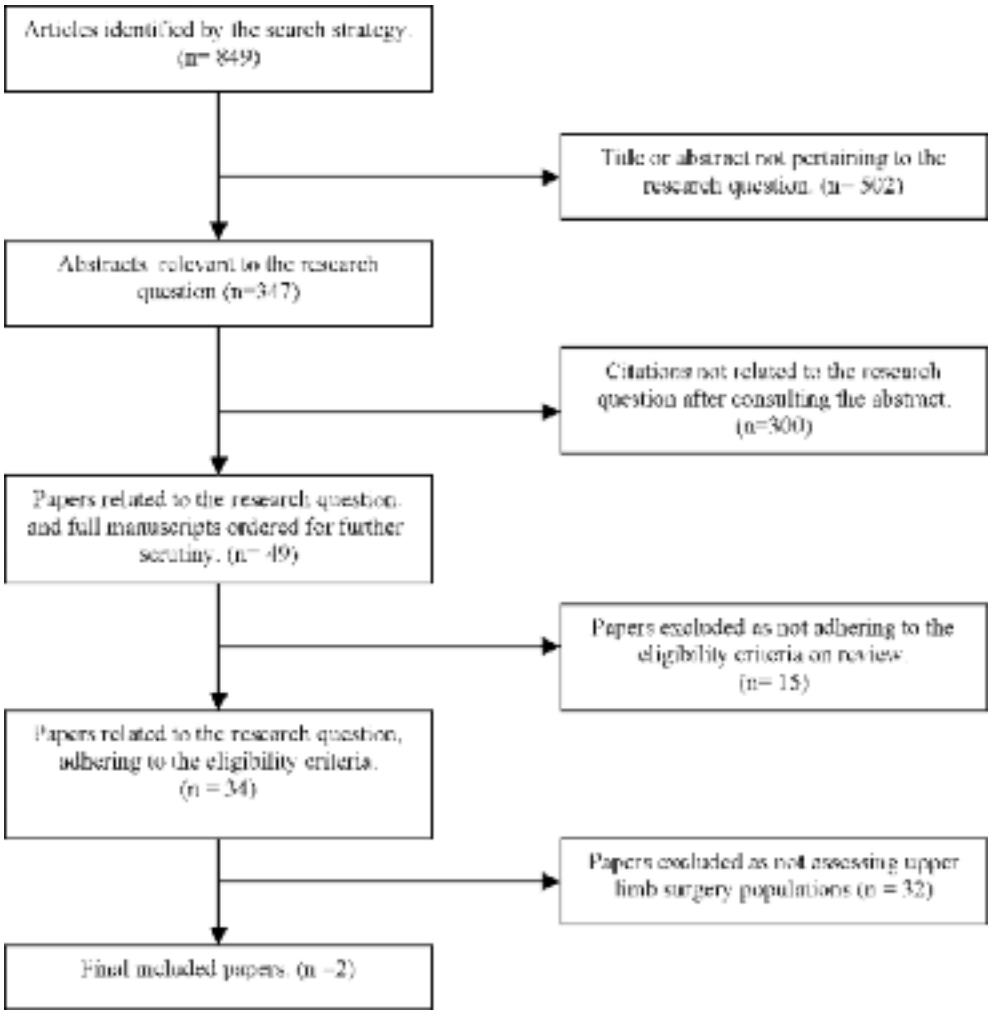

Fig. 1. — A Quality for Reporting Meta-analysis (QUORUM) flow chart to illustrate the identification of papers included in this review.

Meta-analysis was carried out using REVMAN software (version 5.0 for Windows. Copenhagen : The Nordic Cochrane Centre, The Cochrane Collaboration, 2008).

Critical appraisal

Methodological quality of each included study was assessed using the Cochrane Bone, Joint and Muscle Trauma Group quality assessment tool *(23)* by the two reviewers (CH,TS). Any disagreements were resolved through discussion. This appraisal tool has been designed to assess the methodological quality of randomised controlled trials and has been widely used *(15,16)*.

RESULTS

Search strategy : Of the initial 849 citations identified, 2 specifically compare intra- and post-operative outcomes of elbow, forearm, wrist or hand surgery performed with or without a tourniquet (fig 1). These included 32 patients with surgically treated forearm fractures *(28)* and 23 patients who under-

Table I. — Population characteristics

Paper (date)	Operation	Sample		Mean age (years)		Gender (m/f)		Tourniquet			Exsanguination	Thromboprophylaxis
								Location	Pressure (mmHg)	Duration		
		Limbs	Pts	T+	T-	T+	T-					
Braithwaite *et al* (2)	Bilateral CTD	23	23	N/S	N/S	N/S	N/S	Above elbow	N/S	N/S	Elevation and manual compression	N/S
Ömeroğlu *et al* (28)	Forearm ORIF	32	32	26.5	27.4	12/4	12/4	N/S	200-250 mmHg	53.3 and 83.0	Esmarch bandage	N/S

CTD – Carpal Tunnel Decompression
F – Females
M – Males
mmHg – millimetres of mercury
N/S – Not significant
ORIF – Open Reduction Internal Fixation
Pts – Patients
T+ - Tourniquet assisted surgery
T- - Surgery with Tourniquet.

went bilateral carpal tunnel decompression (2). The demographic details of these studies are presented as table I.

Analysis : These articles assessed three domains : pain, operative time and visualisation. When comparing the findings from the two studies identified, the only outcome which did not show statistical heterogeneity was visual analogue score (VAS) pain. They reported that there was no statistically significant difference between tourniquet and non-tourniquet procedures (MD = 8.72 ; 95% confidence interval, CI = -23.06 to 5.63 ; figure 2). Ömeroğlu *et al* (28) also assessed present pain intensity (PPI) scores. Conversely, this study reported a significant difference between the non-tourniquet and the tourniquet group during the first 2 post-operative days, where non-tourniquet patients reported lower pain scores (MD = 1.30 ; 95% CI = 0.34 to 2.26 ; p = 0.006).

There was no statistically significant difference in operative duration between tourniquet to non-tourniquet procedures in Ömeroğlu *et al*'s (28) study. Conversely, Braithwaite *et al* (2) reported significantly shorter operative time in the tourniquet group ($p < 0.01$) ($I^2 = 49\%$; $p = 0.16$). Surgical difficulty and visualisation was only assessed in Braithwaite *et al*'s (2) study. This reported that surgeon's perception of operative difficulty was significantly lower in procedures with a tourniquet, than those without ($p < 0.01$).

Critical appraisal : The evidence base had a number of methodological limitations (table II). The outcome measures selected were appropriate in both studies reviewed to assess the effects of tourniquet use in upper limb surgery. Whilst baseline comparability between the groups was only established to Braithwaite *et al's* (2), both articles indicated that the surgical intervention and post-operative care was identical between the groups, with the exception of tourniquet application. Subject, interventionist and assessor blinding was poorly established between the studies, where only Ömeroğlu *et al* (28) blinded their assessor for clinical evaluation. Both articles poorly documented the randomisation process for their samples. Neither study employed a sufficient follow-up period, nor assessed their results by intent-to-treat methods. The limited samples sizes recruited were not based on power calculations.

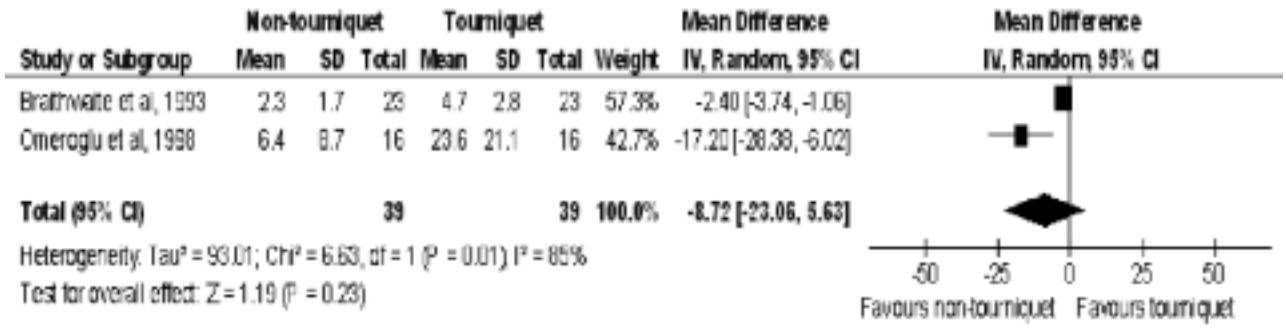

Fig. 2. — Forest plot assessing VAS pain score in upper limb surgery with or without tourniquet

Table II. — Cochrane Musculoskeletal Group methodological quality assessment scheme

	Braithwaite *et al* (2)	Ömeroğlu *et al* (28)
Assignment concealed prior to allocation	×	×
Intention-to-treat analysis	×	×
Assessors blinded	×	✓
Baseline characteristics comparable	✓	×
Participants blinded	×	×
Blinded interventionist	×	×
Identical additional care	✓	✓
Eligibility criteria clearly defined	×	✓
Interventions clearly defined	✓	✓
Outcome measures clearly defined	✓	✓
Outcome measures appropriate	✓	✓
Appropriate follow-up duration	×	×

✓ = satisfied criteria ; × = not satisfied

DISCUSSION

The findings of this study suggest that the surgeon's perception of operative difficulty was significantly lower in procedures with a tourniquet. The effects of tourniquet application on pain perception or operative duration remain conflicting. However, the evidence-base is limited in size and has a number of important methodological limitations. These included poor blinding of assessors and patients to the treatment under investigation, recruiting small samples not justified by power calculations, poorly describing the randomisation process and assessing outcomes over a limited follow-up period.

Study heterogeneity was assessed using the Chi^2 and I^2 statistical tests. Heterogeneity was acknowledged for operative time. A number of variables may have accounted for this within the evidence-base. These included variation in the location, size, use of padding with the tourniquet, exsanguination techniques such as elevation or use of Esmarch bandaging, in addition to differences in inflation pressure, cuff width and deflation. Further study is warranted to determine the effects of each of these variables during upper limb surgery. Furthermore, we recommend that future studies fully document each of these important variables to allow the reviewer to critique and replicate the study methodologies used in each investigation. This would improve external validity and enhance the quality of the evidence-base on this topic.

Odinsson and Finsen (27) assessed the effects of position of tourniquet on the arm, evaluating upper arm and forearm positions for hand surgery.

Although this study suggested that there was little clinical difference between position of the tourniquet and outcome, application of an upper arm tourniquet was described as less difficult than on the forearm. Therefore, we may speculate that the position of tourniquet application is not important in clinical outcome. Further study may be warranted to evaluate this assumption.

The limited size of the evidence base of this topic may seem surprising. This may have been a consequence of publication bias (*8,9*). It therefore remains a concern that conclusions have been drawn on a very small evidence base susceptible to bias (*33*). Only following further study investigating the effects of tourniquet application with similar populations in Ömeroğlu *et al* (*28*) and Braithwaite *et al's* (*2*) studies, could we determine whether publication bias influences the findings of this review. Similarly, no literature was identified assessing the efficacy of tourniquet use during elbow surgery or surgical fixation of wrist fractures. Given the frequency of wrist fractures managed surgically (*36*), further study is recommended to evaluate the effects of tourniquet use in alternative upper limb surgery such as open reduction and internal fixation of elbow, wrist and hand fractures as well as upper limb arthroplasty surgery. Only following this will we be able to determine whether a tourniquet is indicated in upper limb orthopaedic surgery.

Post-operative pain was assessed in each of the investigations reviewed. The literature has suggested a number of different causes for tourniquet pain (*18*). One theory is that intra-operative hypertension during surgery with tourniquet and general anaesthetic may be related to increased serum cortisol and norepinephrine concentrations in response to transmission of pain impulses to the central nervous system from nociceptors affected by inflation of the cuff (*6,7,23*). Persistent noxious input to the central nervous system may cause increased spontaneous activity, increased responsiveness to afferent input and expansion of the peripheral receptive field of dorsal horn neurons (*5*). Therefore afferent pain impulses from inflation of a tourniquet may increase postoperative pain (*18*). The deflation of the tourniquet has also been associated with hyperaemia and increase in limb size (*31*). This may also contribute to pain through the compression of peripheral nerves near the surgical site (*18*). Further study to assess the relationship of post-operative pain following a variety of different surgical procedures, and tourniquet pressures or locations is warranted to further understand the relationship between pain and differing tourniquet applications.

A random-effects analysis method was utilized in this study. This was chosen after identifying methodological heterogeneity between studies primarily on surgical intervention, even though the effect of tourniquet use was assessed throughout. Accordingly, a fixed-effect meta-analysis was deemed inappropriate, requiring the assumption that the observed differences among study results are solely due to chance, and not accounting for heterogeneity (*10*). However, random-effects models, where heterogeneity is evident, result in wider confidence intervals for the average intervention effect compared to analysis with fixed-effect methods, making claims on statistical significance more conservative (*4*). For this reason factors such as operative time and VAS pain were shown as non-significant, whereas with a fixed-effect model, this parameter was significantly less in the tourniquet, than non-tourniquet group (operative time – MD = 2.37 ; 95% CI = 0.68 to 4.06 ; VAS pain – MD = 2.61 ; 95% CI = -3.94 to -1.28). Further studies assessing study populations after specific upper limb surgery may reduce heterogeneity between primary studies, and therefore provide a more informed decision of the application of tourniquets for specific elbow, forearm, wrist and hand procedures.

CONCLUSIONS

There is limited evidence that tourniquet may reduce surgeons' technical difficulty in upper limb surgical procedures. There remains confusion as to whether the application of a tourniquet can influence pain perception or operative duration. The evidence-base is presently limited in both size and methodological quality. Further study is warranted to determine the efficacy of tourniquet for elbow, forearm, wrist and hand surgery.

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