International Journal of Surgery 32 (2016) 109–115

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.journal-surgery.net

Review

A comparison of the Cook-Swartz Doppler with conventional clinical methods for free flap monitoring: A systematic review and a meta-analysis

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HIGHLIGHTS

- We compared implantable Cook-Swartz Doppler and clinical monitoring methods.
- We performed a systematic review with meta-analysis on two-arm studies that examined these two free flap monitoring methods.
- Implantable Cook-Swartz Doppler had significantly better rates of free flap success and salvage than the clinical methods.

ARTICLE INFO

Article history:
Received 3 June 2015
Received in revised form
7 June 2016
Accepted 18 June 2016
Available online 21 June 2016

Keywords:
Implantable Doppler
Free flap
Meta-analysis
Cook-Swartz Doppler

ABSTRACT

Introduction: Currently there is no consensus on what is the optimal method for monitoring free flaps. Our meta-analysis compared the free flap success and salvage rates of Cook-Swartz Implantable Doppler monitoring with clinical monitoring to gain insight into the relative benefit of these systems.
Methods: Medline, Cochrane, EMBASE, and Google Scholar databases were searched until January 16, 2016. Search terms included free flap surgery, free flap microsurgery and implantable Doppler. Studies were included if they involved the comparison of Cook-Swartz Doppler and clinical assessment for monitoring free flap function. Studies using free flap monitoring as an outcome measure for drug treatment were also excluded. Sensitivity analysis using the leave-one-out approach was used to assay the reliability of the findings.
Results: Initial search identified 14 studies, of which five studies were included in the meta-analysis. Cook-Swartz Doppler had significantly better rate of free flap success and salvage than clinical monitoring methods (P values $\leq$ 0.006). Data did not markedly changed when each study was removed in turn, showing reliability of the findings.
Discussion: The Cook-Swartz Doppler as a monitoring method may result in a higher rate of free flap success and salvaging but also a greater frequency of false positives than conventional methods. Our analysis is limited by designs of included studies and by heterogeneity of clinical monitoring techniques.
Conclusions: More studies are needed to evaluate if Cook-Swartz Doppler can be used alone, or to be better used as an adjunctive technique to complement the clinical method of monitoring.
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1. Introduction

Free-tissue transfer (free flap) is an integral part of many reconstructive surgeries [1–4]. Success of a free flap depends on continuous arterial inflow and venous outflow through microvascular anastomosis, until peripheral in-growth of new vessels establishes revascularization in the tissue [4]. If the circulation cannot be re-established, salvage of the free flap is difficult due to obstruction of the peripheral blood flow after increasing periods of ischemia [5]. Currently, free flap loss rate is less than 4%, but it is still an important complication [6].

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http://dx.doi.org/10.1016/j.ijsu.2016.06.034
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Detecting vascular compromise as early as possible is critical for maximizing the free flap success and the chance of free flap salvage. There are two major methods for monitoring free flaps: physical examination and implantable, internal, monitoring methods. Physical examinations typically include monitoring capillary refill time, skin color, skin turgor, temperature, and external Doppler [7]. Implantable probes, such as the Cook-Swartz Doppler, are used to monitor both veins and arteries, and have the advantage that they provide real-time qualitative information about blood flow [7,8]. Clinical studies that evaluated the Cook-Swartz Doppler for monitoring free flaps have found the overall free flap success rate to be between 95% and 98% [6,9–12].

Studies that compare the use of implantable Cook-Swartz Doppler with clinical monitoring are limited and have had inconsistent results. Moreover, very few studies have assessed the free flap salvage rate using the Cook-Swartz Doppler monitoring method. Our meta-analysis compared the free flap success and salvage rates of using Cook-Swartz Doppler and clinical methods, in order to further investigate the relative strength of each monitoring system.

2. Methods

2.1. Search strategy

Medline, Cochrane, EMBASE, Google Scholar databases were searched until January 16, 2016, for prospective and retrospective studies that evaluated the effectiveness of implantable Cook-Swartz Doppler compared with other techniques for monitoring the function of free flap reconstructions. Search terms included free flap surgery or free flap microsurgery and implantable Doppler, flap monitoring, Cook-Swartz Doppler, clinical methods. Studies were included if they had two treatment arms that compared Cook-Swartz Doppler with clinical methods and reported flap success and/or salvage rates. Non-English publications were excluded. Abstracts, case reports, and symposium proceedings were also excluded. Clinical studies that used free flap monitoring as an outcome measure for drug treatment were also excluded. All potential studies were identified and reviewed by two independent reviewers. A third reviewer was consulted to resolve any disagreements or uncertainties.

2.2. Data extraction and quality assessment

The following information was extracted from studies that met the inclusion criteria: the name of the first author, year of publication, study design, number of participants in each treatment group, participants' age and gender, free flap success, salvage rates, and number of flaps, flap success, revised cases, flap salvages, and flap loss in salvage.

The quality of the data of the included studies was evaluated using the Newcastle-Ottawa Quality Assessment Scale [13]. The Newcastle-Ottawa Scale is a valid tool for evaluating non-randomized studies with regard to three criteria: patient selection, comparability of study groups, and outcome assessment. Quality assessment was also performed by two independent reviewers and a third reviewer was consulted for any uncertainties.

2.3. Statistical analysis

The key outcome measures were flap success rate, as defined by complete or partial flap survival, and flap salvage free rate (salvage flaps/compromised flaps x 100%) and flap loss rate. The differences in flap success rate, flap salvage rate and flap loss rate were compared between participants who were monitored using Cook-Swartz Doppler and those monitored by standard clinical assessment. Odds ratios (OR) with 95% confidence intervals (CI) were calculated for binary outcomes and were compared between groups. For the rates of free flap success, free flap salvage and flap loss, an OR > 1 indicated that the Cook-Swartz Doppler had higher rate of free flap success, free flap salvage, and flap loss, and an OR < 1 indicated clinical assessment had higher rate of free flap success, free flap salvage, and flap loss. A χ^2-based test of homogeneity was performed using Cochran's Q statistic and I^2. I^2 illustrates the percentage of the total variability ineffect estimates among trials that are due to heterogeneityrather than chance.Random-effects models of analysis (DerSimonian-Laird method) were used if heterogeneity was detected ($I^2 > 50\%$). Otherwise, fixed-effects models (Mantel-Haenszel method) were considered. Pooled ORs were calculated and a 2-sided P value < 0.05 was considered to indicate statistical significance. Sensitivity analysis was carried out for the outcomes using the leave-one-out approach. As more than five studies are required to detect funnel plot asymmetry [14], publication bias was not assessed in this meta-analysis as only 5 studies were included. All analyses were performed using Comprehensive Meta-Analysis statistical software, version 2.0 (Biostat, Englewood, NJ, USA).

3. Results

The initial search identified 38 studies, in which 33 were ultimately eliminated for not meeting inclusion/exclusion criteria (Fig. 1). Of the 14 studies chosen to receive full-text reviewing, five were eliminated for being single-arm studies, and four were eliminated for not providing sufficient or relevant data or not meeting the selection criteria. The remaining five studies were included in the meta-analysis [15–19].

All five studies included in the meta-analysis were retrospective in design (Table 1). The number of patients in the included five studies ranged from 40 to 630 (total = 1995). The type of free-flap surgeries varied across the studies and included surgery for the area of the head and neck, breast reconstruction, trauma, orthopedic oncology, reanimation, trauma, and neurosurgery. The age of

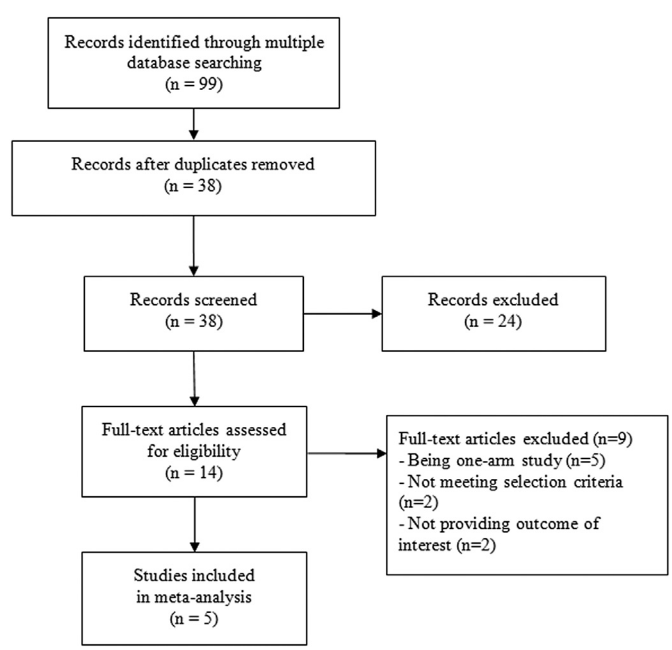

Fig. 1. Flow chart of study selection.

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