

# The Role of Flow Couplers in Free Flap Monitoring: Evidence from a Systematic Review and Meta-Analysis

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## Introduction

Microsurgical free tissue transfer is the **cornerstone of reconstructive surgery**, but its success is critically dependent on **early detection of vascular compromise**. Traditional monitoring methods such as **clinical observation and hand-held Doppler** are limited by **observer dependency** and **intermittent assessments**. Furthermore, in **buried flaps** these methods are often inadequate.

**Venous flow couplers (FCs)** combine a microvascular anastomotic device with an **implantable Doppler probe**, enabling **continuous, real-time monitoring** of venous outflow at the anastomotic site.

This systematic review and meta-analysis aimed to **evaluate the diagnostic accuracy of FCs**, assess their **impact on flap survival**, and compare them with **conventional monitoring modalities**, with particular focus on reconstruction with buried flaps.

## Methods

A **systematic literature search** of PubMed, Web of Science and Cochrane Library was performed up to March 2025, following PRISMA guidelines.

Eligible studies included **clinical series, cohort studies, and randomized trials** reporting FC use in free flap reconstruction. Extracted outcomes included **flap survival and failure rates, venous thrombosis, and diagnostic accuracy** (sensitivity, specificity, predictive values).

Risk of bias was assessed with Downs and Black's checklist.

Meta-analyses were conducted using a random-effects model, with heterogeneity quantified by I<sup>2</sup> statistics.

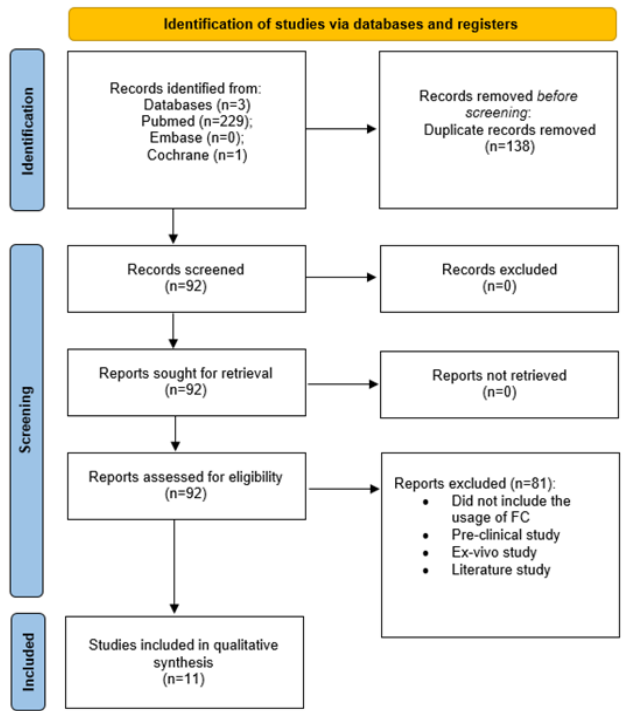


Figure 1: PRISMA 2020 flow diagram on the database search

## Results

A total of **11 studies** comprising **1,775 free flaps** were included, of which **876 (49.3%)** were monitored with FCs. The devices were most frequently used in buried flaps (DIEP, fibula).

Reported flap survival in FC-monitored reconstructions ranged from 94.6% to 99.1%. Pooled analysis showed **sensitivity of 96.5%** and **specificity of 90.9%** for detecting flap compromise.

Meta-flap failure rates were 2.2% in FC-monitored flaps versus 3.1% in controls, without any statistically significant difference. **False-positive signal loss** occurred in up to **13.6% of cases**, usually due to **technical artifacts** (wire malposition, flap inset tension, venous kinking), while **false negatives were rare**. FCs consistently exhibited a **high negative predictive value**, reliably confirming flap viability, when a signal was present.

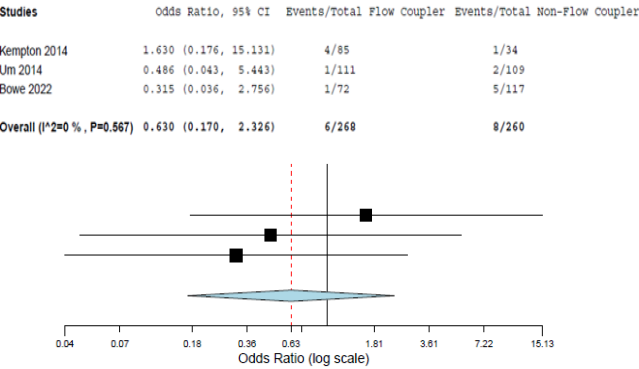


Figure 2. Forest plot depicting effect estimates regarding the flap failure rates of FC and NFC by OR and corresponding 95% CI. Black square: Point estimate of the effect for a single study. Black line: Confidence interval. Diamond: Overall effect estimate. Weights of studies were as follows: 34.39% (Kempton et al.), 29.27% (Um et al.), 36.34% (Bowe et al.)

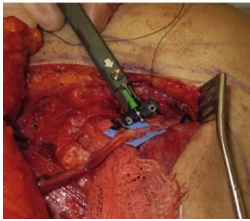


Figure 3: Synovis GEM 2755-FC FlowCoupler System

## Discussion

Venous FCs represent a **highly sensitive, operator-independent monitoring tool** that provides **continuous detection of venous thrombosis**, the most common cause of flap failure. Their value is greatest in **buried reconstructions**, where they allow monitoring in the absence of visible clinical signs and can **eliminate external monitoring skin paddles**, thereby arguably improving **aesthetic outcomes**.

However, their **specificity remains modest**, and **false-positive signal losses** may lead to **unnecessary re-explorations** and **increased morbidity**.

Furthermore, FCs are **incapable of detecting arterial insufficiency**, necessitating their integration into **multimodal monitoring strategies**. The effectiveness of FCs is strongly influenced by surgical expertise and the implementation of standardized institutional protocols.

Looking forward, prospective multicenter studies and the development of dual arterial-venous monitoring systems are needed to optimize flap surveillance and reduce variability in outcomes.

## Conclusions

The **venous flow coupler** is a **valuable adjunct in free flap monitoring**, offering **high sensitivity and strong negative predictive value** for detecting venous compromise, especially in **buried flaps** where conventional methods are limited.

Despite these advantages, its **limited specificity** necessitates its **integration into multimodal monitoring strategies** rather than standalone use. With **refined technical application, standardized protocols, and further multicenter evidence**, FCs have the potential to significantly enhance **postoperative safety and flap salvage rates** in reconstructive microsurgery.

