

## REVIEW ARTICLE

# Isolated forearm technique: a meta-analysis of connected consciousness during different general anaesthesia regimens

F. Linassi<sup>1,\*</sup>, P. Zanatta<sup>2</sup>, P. Tellaroli<sup>3</sup>, G. Ori<sup>1</sup> and M. Carron<sup>1</sup>

<sup>1</sup>Department of Medicine, Anaesthesiology and Intensive Care, University of Padova, Padova, Italy, <sup>2</sup>Department of Anaesthesia and Intensive Care, Integrated University Hospital of Verona, Verona, Italy and <sup>3</sup>Department of Cardiac, Thoracic and Vascular Sciences, University of Padova, Padova, Italy

\*Corresponding author. E-mail: [federico.linassi@studenti.unipd.it](mailto:federico.linassi@studenti.unipd.it)

## Abstract

**Background:** General anaesthesia should prevent patients from experiencing surgery, defined as connected consciousness. The isolated forearm technique (IFT) is the current gold standard for connected consciousness monitoring. We evaluated the efficacy of different anaesthesia regimens in preventing IFT responses.

**Methods:** We conducted a systematic review with meta-analysis of studies evaluating IFT in adults. Proportions of IFT-positive patients were compared for inhalational versus intravenous anaesthesia and anaesthesia brain monitor (ABM)-guided versus non-ABM-guided.

**Results:** Of 1131 patients in 22 studies, 393 (34.8%) had an IFT response during induction or maintenance. IFT-positive patients were less frequent during induction (19.7% [95% CI, 17.5–22.1]) than during maintenance (31.2% [95% CI, 27.8–34.8]). Proportions of IFT-positive patients during induction and maintenance were similar for inhalational (0.51 [95% CI, 0.38–0.65]) and intravenous (0.52 [95% CI, 0.26–0.77]) anaesthesia, but during maintenance were lower with inhalational (0.18 [95% CI, 0.08–0.38]) than with intravenous (0.48 [95% CI, 0.24–0.73]) anaesthesia. Proportions of IFT-positive patients during induction and maintenance were not significantly different for ABM-guided (0.64 [95% CI, 0.39–0.83]) and non-ABM-guided (0.48 [95% CI, 0.34–0.62]) anaesthesia but during maintenance were lower with non-ABM-guided (0.19 [95% CI, 0.09–0.37]) than with ABM-guided (0.57 [95% CI, 0.34–0.77]). Proportions of IFT-positive patients decreased significantly with increasing age and premedication use. Of the 34 anaesthesia regimens, 16 were inadequate. Studies had low methodological quality (only seven randomised controlled trials) and significant heterogeneity.

**Conclusions:** Standard general anaesthesia regimens might not prevent connected consciousness. More accurate anaesthesia brain monitor methodology to reduce the likelihood of connected consciousness is desirable.

**Keywords:** consciousness monitors; surgical equipment; intraoperative awareness; intraoperative complications; intraoperative monitoring; surgical procedures

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### Editor's key points

- A systematic review and meta-analysis was performed of studies using the isolated forearm technique (IFT) to monitor connected consciousness during general anaesthesia.
- Although the studies had low methodological quality and significant heterogeneity, potentially important differences in anaesthesia techniques associated with positive IFT responses were observed.
- Anaesthesia brain monitor-guided anaesthesia appears less likely to prevent connected consciousness during maintenance of anaesthesia, particularly when intravenous anaesthesia is used.
- Young age and lack of premedication increased the likelihood of a positive IFT response during maintenance of anaesthesia.

One of the most important objectives of general anaesthesia is to prevent the patient from experiencing surgery, which has been defined as connected consciousness.<sup>1</sup> Various methods have been proposed to monitor connected consciousness. The isolated forearm technique (IFT) and bispectral index (BIS) monitoring are the two most important methods. IFT is a qualitative method: in response to verbal instructions, the patient either does or does not move the forearm that has been isolated from the systemic circulation. Isolation is accomplished using a cuffed upper arm tourniquet, which is inflated before the administration of neuromuscular blocking agents to a pressure higher than the systolic arterial pressure. Movement of the isolated forearm in response to instructions is considered a positive IFT test, which can be interpreted as a sign of connected consciousness.<sup>1</sup> IFT is recognised as the current gold standard for consciousness monitoring in the presence of neuromuscular blocking agents.<sup>2</sup>

BIS monitoring is a quantitative method based on the bispectral processing of the spontaneous cortical activity of the monolateral frontal cortex, which determines the harmonic and phase relations amongst various EEG frequencies.<sup>3,4</sup> BIS values between 40 and 60 are generally recommended as adequate targets for guiding the administration of hypnotics during general anaesthesia.<sup>5,6</sup> However, some patients have been reported to exhibit a positive IFT response during surgery with BIS values in this range, thereby suggesting that connected consciousness might not be avoided at these levels.<sup>7–10</sup> Further increasing the uncertainty about the role of processed EEG anaesthesia brain monitors (ABMs) in preventing connected consciousness, a recent study showed that BIS can fall below 50 in awake volunteers after neuromuscular block.<sup>11</sup> All of these data underline the fact that the processes involved in the production of anaesthesia are still far from being well understood and that ABM-guided anaesthesia cannot completely eliminate the risk of insufficient anaesthesia: a patient believed to be deeply anaesthetised in the operating room may still be able to hear and respond to voices of operating-room personnel, indicating the presence of connected consciousness.

The magnitude of the problem of connected consciousness is not well established. To quantify the incidence of connected consciousness and related explicit recall in patients undergoing general anaesthesia, we conducted a

systematic review with meta-analysis of adult-only studies, in which IFT was used. We determined the overall incidence of connected consciousness (defined by a positive IFT test) and explicit recall, and performed subgroup analyses to assess the effects of the type of anaesthesia (i.v. or inhalation) and the use or non-use of ABM during the induction of anaesthesia and surgery. We also performed a regression meta-analysis to identify the factors associated with a positive IFT test or explicit recall.

## Methods

### Search strategy

We performed a systematic review with meta-analysis of previously published studies, in which the level of consciousness during general anaesthesia was monitored with IFT. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) when designing the study and preparing this report.

We conducted a comprehensive search of the Medline, Embase, and Google Scholar databases using the following Medical Subject Headings (MeSH) terms: anaesthesia, brain, consciousness monitors, awareness, mental recall, and surgery. Using the 'AND' function, the MeSH terms were combined with each other and with the following additional terms: isolated forearm technique, IFT, bispectral index, BIS, Narcotrend, anaesthesia brain monitor, and ABM. The search period included articles published between 1977<sup>12</sup> and 2017. No language restrictions were applied for the searches, but only those studies written in English were selected for inclusion in this systematic review. The date of the last search was June 30, 2017.

Two authors (F.L. and P.Z.) independently identified titles and abstracts of potentially eligible studies. The full-text versions of these studies were then reviewed by F.L. and P.Z. to select the studies included in this systematic review. Any disagreements at either the title and abstract screening or full-text review stages were resolved by consensus with input from a third author (M.C.).

### Eligibility and inclusion

Studies were included if they involved patients only  $\geq 18$  yr old, evaluated the use of the IFT to monitor consciousness during anaesthesia, and were controlled or observational trials. Furthermore, studies were excluded if they involved paediatric patients, did not clearly specify the anaesthesia regimen or number of patients who were considered IFT positive (defined in the 'End-point' section), or involved the use of the IFT solely to monitor emergence from anaesthesia. Review articles and case reports were excluded. If the exact timing of IFT responses was not specified, we classified them as occurring during the maintenance phase.

### End-points

We considered four main end-points: the number of IFT-positive patients ('IFT positives') at any time during general anaesthesia (from induction to the end of surgery), the number of IFT positives during the induction phase of anaesthesia, the number of IFT positives during the maintenance phase of anaesthesia (from 10 min after induction to the end of surgery), and the number of patients reporting explicit recall of surgery in the postoperative period. A patient was considered

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