Journal of Clinical Neuroscience 30 (2016) 8–14

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Review

Diagnostic accuracy of somatosensory evoked potential monitoring during scoliosis fusion

Parthasarathy D. Thirumala [a,c,*], Hannah L Cheng [a], Yoon K. Loke [d], D. Kojo Hamilton [a], Jeffrey Balzer [a,b], Donald J. Crammond [a]

[a] Department of Neurologic Surgery, University of Pittsburgh Medical Center, UPMC Presbyterian-Suite-B-400, 200 Lothrop Suite, Pittsburgh, PA 15213, USA
[b] Department of Neuroscience, University of Pittsburgh, Pittsburgh, PA, USA
[c] Department of Neurology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA
[d] Norwich Medical School, University of East Anglia, Norwich, UK

ARTICLE INFO

Article history:
Received 4 November 2015
Accepted 17 January 2016

Keywords:
Idiopathic scoliosis
Intraoperative neurophysiological monitoring
Somatosensory evoked potential

ABSTRACT

The goal of this review was to ascertain the diagnostic accuracy of intraoperative somatosensory evoked potential (SSEP) changes to predict perioperative neurological outcome in patients undergoing spinal deformity surgery to correct adolescent idiopathic scoliosis (AIS). The authors searched PubMed/MEDLINE and World Science databases to retrieve reports and/or experiments from January 1950 through January 2014 for studies on SSEP use during AIS surgery. All motor and sensory deficits were noted in the neurological examination administered after the procedure which was used to determine the effectiveness of SSEP as an intraoperative monitoring technique. Fifteen studies identified a total of 4763 procedures on idiopathic patients. The observed incidence of neurological deficits was 1.11% (53/4763) of the sample population. Of the patients with new postoperative neurological deficits 75.5% (40/53) showed significant SSEP changes, and 24.5% (13/53) did not show significant change. Pooled analysis using the bivariate model showed SSEP change with pooled sensitivity (average 84%, 95% confidence interval 59–95%) and specificity (average 98%, 95% confidence interval 97–99%). The diagnostic odds ratio of a patient who had a new neurological deficit with SSEP changes was a diagnostic odds ratio of 340 (95% confidence interval 125–926). Overall, detection of SSEP changes had excellent discriminant ability with an area under the curve of 0.99. Our meta-analysis covering 4763 operations on idiopathic patients showed that it is a highly sensitive and specific test and that iatrogenic spinal cord injury resulting in new neurological deficits was 340 times more likely to have changes in SSEP compared to those without any new deficits.

1. Introduction

A devastating complication of correcting spinal deformity is iatrogenic spinal cord injury resulting in paraplegia or paraparesis [1,2]. Idiopathic scoliosis (IS) is considered the most common form of spinal deformation [3] with no recognized etiology[4]. The prevalence of adolescent idiopathic scoliosis (AIS) occurs is 2–4% of the population between 10–16 years of age [5], for which corrective surgery is the most effective treatment option in advanced cases [5,6]. However, surgical intervention puts the integrity of the spinal cord at risk. Surgical complications are most often related to the placement of spinal instruments or the use of instrumentation to correct the spinal deformity by causing direct injury to the spinal cord or to the spinal vasculature [7]. Even though the incidence of neurological deficits is reported to be approximately 1% [2], this is a devastating complication with significant morbidity [8] in patients who are generally young and otherwise healthy. The use of intraoperative neurophysiological monitoring of spinal cord function has been shown to reduce the risk of motor deficits or paraplegia [9,10] and is commonly used in surgical procedures with potential for incurring spinal cord injury [9,11]. Intraoperative neurophysiological monitoring is a rapidly growing subspecialty of neurology [12] being utilized in more than 800,000 surgical procedures in the USA annually to reduce the incidence of neurological complications [10].

Somatosensory evoked potential (SSEP) monitoring during corrective IS surgery plays an important role in reducing the incidence of devastating neurological deficits by the continuous monitoring of dorsal column function of the spinal cord [13,9]. It is reported

* Corresponding author. Tel.: +1 412 648 2582; fax: +1 412 383 9899.
E-mail address: thirumalapd@upmc.edu (P.D. Thirumala).

http://dx.doi.org/10.1016/j.jocn.2016.01.017
0967-5868/

that significant changes of SSEP may correspond to correction of the spinal deformity [9,10,14], and reflect possible permanent neurological injury if not corrected. Significant changes in SSEP are defined as a 50% decrease in amplitude and/or a 10% increase in latency of the cortical SSEP waveform when compared to baseline values [15–17]. SSEP monitoring can detect impending deficits with high sensitivity and specificity [9,10,14]. Transcranial motor evoked potential (TcMEP) monitoring of the corticospinal pathway has also been shown to identify impending motor deficits [18,19].

The primary aim of this study was to conduct a systematic review of the scientific literature in order to evaluate whether changes in SSEP during AIS procedures are diagnostic for new onset postoperative neurological deficits. The goal of this review was to ascertain the sensitivity, specificity, diagnostic odds ratio, and area under the receiver operating characteristic curves of the intraoperative SSEP changes in relation to neurological outcome in patients undergoing surgery to correct AIS. This information will establish SSEP as a real-time biomarker of iatrogenic spinal cord injury. Furthermore, this information can be utilized to evaluate pharmacological therapies directed at these patients to treat iatrogenic spinal cord injury. To our knowledge, no therapies have been tested to treat iatrogenic spinal cord injury.

2. Methods

2.1. Type of studies

Peer-reviewed publications were included in the assessment if they (1) were randomized controlled trials, prospective, or retrospective cohort reviews, (2) conducted in patients with AIS, (3) conducted on surgical procedures for AIS that utilized intraoperative SSEP monitoring, (4) reported immediate postoperative neurological assessment, (5) included a total sample size ⩾25 patients, and (6) were published in English. All study participants underwent a surgical procedure to treat AIS. No patient was excluded due to age in the study. For the purposes of the study, SSEP monitoring was the index text, and was compared to a reference standard (below). There were no restrictions on additional monitoring modalities. The study focused on patients with AIS of the thoracic and lumbar spine. Postoperative neurological deficits were defined as any new deficit or loss of motor or sensory function recorded in the immediate postoperative time period. It should also be noted that postoperative neurological examinations were typically not performed by a neurologist and may not have complied with any common reference standard.

2.2. Literature search criteria and strategy

The following terms were used to identify patients who had AIS: "scoliosis," "spinal deformity," or "corrective spinal deformity". We utilized the terms "intraoperative neurophysiological monitoring," "somatosensory evoked potentials," "somatosensory evoked potential," or "intraoperative neurophysiological monitoring," to identify patients who underwent SSEP monitoring during scoliosis surgery. The authors searched PubMed/MEDLINE and World Science databases for reference lists of retrieved reports and/or experiments from January 1950 through January 2013 for studies on SSEP use during AIS surgery.

2.3. Data extraction and analysis

Two authors (H.LC. and P.D.T.) independently screened all titles and abstracts to identify studies that met the inclusion criteria and extracted relevant articles (Fig. 1). Subsequently, each author constructed an Excel spreadsheet (Microsoft, Redmond, WA, USA) listing articles that were to be eliminated and the reasons for the elimination dictated by the number corresponding to the appropriate inclusion criteria (i.e.1–6). The two Excel spreadsheets were compared and after disagreements were reconciled, a final list of articles that met the study inclusion criteria was assembled (Table 1).

The following data was extracted from each study: (1) first author and year of publication, (2) study design, (3) SSEP and other intraoperative neurophysiological monitoring modalities used and when SSEP baselines were obtained, (4) study data, including total sample size, idiopathic sample size, SSEP changes, reversible and/or irreversible changes to SSEP, and (5) outcome data, including reversible or irreversible neurological deficit, which was deemed any persistent neurological motor deficit (weakness, paraplegia) or sensory deficits which was present postoperatively as independently stated by each individual study. SSEP changes, explicitly classified by each paper, were classified as a greater than 50% decrease in the amplitude and/or a 10% increase in latency of cortical N20-P25 complex of the upper extremity SSEP. If it was stated differently, we planned to do a covariate analysis in order to determine its effect on the outcome. We determined an irreversible SSEP change to be a reported significant amplitude and/or latency change which did not return to baseline at the end of the procedure. Further, a reversible SSEP change was a reported intraoperative change that returned to baseline at the end of the operation.

2.4. Data extraction and management

The number of true positives (TP), false negatives (FN), false positives (FP), and true negatives (TN) in patients with AIS was extracted and tabulated for each study. TP were patients with SSEP changes and with a new postoperative motor deficit. FN were patients with no SSEP changes and with a new postoperative motor deficit. TN were patients with no SSEP changes and no new postoperative motor deficits. FP were patients with SSEP changes and without a new postoperative motor deficit.

2.5. Assessment of methodological quality

The review authors used the quality assessment of diagnostic accuracy studies (QUADAS 2) tool to assess the susceptibility to bias of the included studies [20]. We assessed patient selection, index test, reference standard, and flow and timing as the four domains. Patient selection refers to avoiding nonconsecutive or nonrandom sampling, case-control, or inappropriate exclusion. The index test refers to proper SSEP monitoring. The reference standard refers to proper testing for neurological function. Flow and timing refer to the interval between the index and reference tests, whether all patients received the same reference test and whether all patients were included in the analysis. If the answers to all signaling questions in a domain are "yes" then the "low" risk grade is given. If the answer to any signaling question is "no" then a "high" risk grade is given. The "unclear" category was only used where the reported data was insufficient to permit a judgment. The methodological quality of the included studies was assessed independently by two review authors and disagreement was resolved by reexamination of primary literature.

2.6. Statistical analysis

We used Stata 13 for the statistical analyzes (StataCorp, College Station, TX, USA). Meta-analysis was conducted using the bivariate model to fit the data into a hierarchical summary receiver operating curve (HSROC), which is a technique that yields useful summary estimates of diagnostic test performance [21]. We were also able to calculate the area under the receiver operating curve