VALUE IN HEALTH 18 (2015) 605–613

Available online at www.sciencedirect.com

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

Goal-Directed Fluid Therapy Guided by Cardiac Monitoring During High-Risk Abdominal Surgery in Adult Patients: Cost-Effectiveness Analysis of Esophageal Doppler and Arterial Pulse Pressure Waveform Analysis

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ABSTRACT

Background: Several minimally invasive techniques for cardiac output monitoring such as the esophageal Doppler (ED) and arterial pulse pressure waveform analysis (APPWA) have been shown to improve surgical outcomes compared with conventional clinical assessment (CCA). **Objective:** To evaluate the cost-effectiveness of these techniques in high-risk abdominal surgery from the perspective of the French public health insurance fund. **Methods:** An analytical decision model was constructed to compare the cost-effectiveness of ED, APPWA, and CCA. Effectiveness data were defined from meta-analyses of randomized clinical trials. The clinical end points were avoidance of hospital mortality and avoidance of major complications. Hospital costs were estimated by the cost of corresponding diagnosis-related groups. **Results:** Both goal-directed therapy strategies evaluated were more effective and less costly than CCA. Perioperative mortality and the rate of major complications were reduced by the use of ED and APPWA. Cost reduction was mainly due to the decrease in the rate of major complications. APPWA was dominant compared with ED in 71.6% and 27.6% and dominated in 23.8% and 20.8% of the cases when the end point considered was "major complications avoided" and "death avoided," respectively. Regarding cost per death avoided, APPWA was more likely to be cost-effective than ED in a wide range of willingness to pay. **Conclusions:** Cardiac output monitoring during high-risk abdominal surgery is cost-effective and is associated with a reduced rate of hospital mortality and major complications, whatever the device used. The two devices evaluated had negligible costs compared with the observed reduction in hospital costs. Our comparative studies suggest a larger effect with APPWA that needs to be confirmed by further studies.

Keywords: abdominal surgery, arterial pulse pressure waveform analysis, cost-effectiveness, esophageal Doppler, goal-directed fluid therapy.

Introduction

Goal-directed fluid therapy based on cardiac output monitoring during high-risk surgery is associated with better tissue perfusion, decreased risk of perioperative complications, improved postoperative rehabilitation, and reduction in hospital length of stay compared with standard hemodynamic monitoring based on clinical parameters (blood pressure, heart rate, and urinary output) or use of a central venous catheter [1–3].

Initially, the criterion standard for cardiac output monitoring was the thermodilution method, which required the insertion of a pulmonary artery catheter, an invasive procedure with significant morbidity and whose clinical benefit has been questioned [4].

Over the last 15 years, several new minimally invasive devices have been developed and have become commercially available: esophageal Doppler (ED), the most widely used technique, measures blood flow velocity in the descending thoracic aorta through a probe inserted in a patient's esophagus during general anesthesia. This technique allows for continuous estimation of the corrected flow time, stroke volume, and cardiac output. A predetermined decision algorithm is used to guide fluid therapy according to the cardiac output variation. Another minimally invasive technique, the arterial pulse pressure waveform analysis (APPWA), allows a similar way to measure continuous cardiac output thanks to an arterial catheter connected to a monitor analyzing pulse pressure waveform.

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1098-3015$36.00 – see front matter

http://dx.doi.org/10.1016/j.jval.2015.04.005

Several randomized control trials (RCTs) and meta-analyses have shown clinical benefit with ED and APPWA compared with conventional clinical assessment (CCA) in high-risk surgery and high dependency units (HDUs) [1,2,5,6]. Two systematic reviews have recently studied the contribution of ED in terms of reduction in the rate of complications, hospital length of stay, and mortality compared with CCA [5,7]. In the United Kingdom, the National Institute of Health and Care Excellence published in 2011 good practice guidelines for ED and has argued that in an enhanced recovery program, the cost saving per patient when ED was used instead of a central venous catheter in the perioperative period was about £1100 based on a 7.5-day hospital stay [8]. These recommendations, however, have been discussed because they were based on a small number of RCTs with quite small and heterogeneous populations: Interventions studied were as diverse as cardiac, orthopedic, and abdominal surgery, in operative rooms or in HDUs [9]. More recently, other RCTs have been published focusing on abdominal surgery [10–15], but their results remain to be synthetized.

Actually, cardiac output monitoring during high-risk surgery is not systematically implemented and costs could be a barrier to its adoption. This is especially disturbing because it can be suspected that, depending on the device used, morbidity, mortality, and length of stay could be different. Economic evaluation can help decision makers reach an optimal allocation of resources [16].

To date, only two economic studies have evaluated ED and have shown that it is an efficient strategy compared with CCA alone [5,17], but, to our knowledge, costs and consequences of using other techniques of minimally invasive cardiac output monitoring such as APPWA have never been investigated.

The aim of this study was to evaluate the cost-effectiveness ratio of ED and APPWA in comparison to that of CCA in intermediate- and high-risk abdominal surgery from the French public health insurance fund perspective.

Methods

Economic Model

A decision tree was constructed to compare the cost-effectiveness ratios of three hemodynamic monitoring and fluid therapy strategies in intermediate- and high-risk abdominal surgery (Fig. 1). Interventions compared were CCA, including measurements of heart rate, blood pressure, and urinary output with or without central venous catheter monitoring; measurement of cardiac output with ED (CardioQ-ODM, Deltex Medical) associated with standard monitoring (ED + CCA); and measurement of cardiac output with APPWA (Vigileo/FloTrac, Edwards Lifesciences) associated with standard monitoring (APPWA + CCA).

Following each strategy, three individual outcomes were possible: death of the patient, occurrence of major complications, and discharge without any major complication, occurring with a probability P depending on the clinical effectiveness of each outcome.

The time horizon considered was the hospital period, extending from entrance until hospital discharge. It was assumed that hemodynamic optimization and fluid administration during surgery would not influence outcomes after discharge. This assumption was also made in all the RCTs.

Clinical-Effectiveness Data

The two effectiveness criteria considered were avoidance of mortality and avoidance of major complications. A complication was considered as major when resulting in hospitalization in the intensive care unit or revision surgery, reported as grade 3 or 4 complications in Dindo et al.'s classification [18].

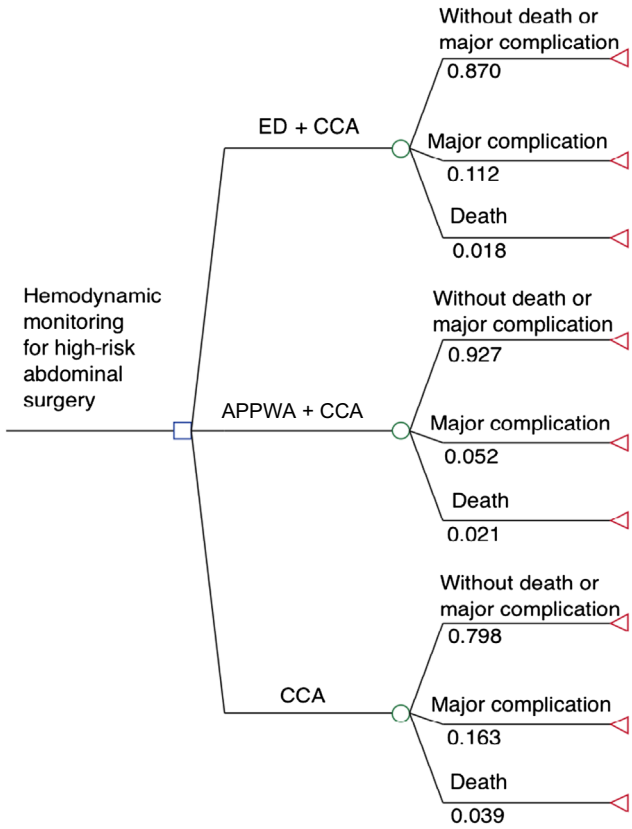

Fig. 1 – Economic decision model tree comparing three strategies of intraoperative hemodynamic monitoring. APPWA, arterial pulse pressure waveform analysis; CCA, conventional clinical assessment; ED, esophageal Doppler.

A comprehensive review of the literature was performed in January 2013 without any time or language restriction using PUBMED, EMBASE, and COCHRANE databases, and complementary research was performed on the basis of the bibliography section of articles, unpublished studies, and proceedings from scientific conferences. Key words used were "esophageal Doppler," "goal directed therapy," hemodynamic," "arterial pulse pressure waveform analysis," and "surgery." All RCTs comparing CCA with a minimally invasive method of cardiac output monitoring during abdominal surgery and related mortality or major complications were included, whatever the number of patients. Studies conducted in pediatrics, in HDUs or in nonabdominal surgery, were excluded. A second author performed data extraction independently, and the methodological quality of the trials was assessed using the Jadad score [19].

Based on the selected articles, meta-analyses of effectiveness data were performed to estimate probabilities.

CCA

For CCA, the probability of an event (death or major complication) corresponded to the overall proportion of the event, and the 95% confidence interval (CI) was calculated from a meta-analysis of single-proportion control groups that we performed, considering all RCTs and comparing the CCA strategy with another strategy (ED + CCA and APPWA + CCA). These values were used for the base-case analysis.

ED and APPWA

For both alternatives to CCA (ED + CCA and APPWA + CCA), the probability for an event (death or major complication) was