Using Cadaver Simulation to Improve Communication and Economy of Movement as Evidence of Progress with the Trans-catheter Aortic Valve Implantation (TAVI) Learning Curve

Conference Paper · July 2014

DOI: 10.13140/2.1.3004.4484

Conference: 2014 Summer Simulation Multiconference, Volume: 26

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Abstract

web: http://surgery.arizona.edu/iCAMP Abstract Trans-catheter Aortic Valve Implantation (TAVI) is an endovascular treatment for critical aortic stenosis. An early " learning curve " is important drawback of TAVI that can dramatically alter patient safety and hospital costs. There is paucity of data regarding the quantification of learning experience associated with the technique. The aim of this study was to assess learning curve in clinical staff involved in the…

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Keywords: Trans-catheter Aortic Valve Implantation, TAVI, Economy of movement, Learning Curve, Robotic Surgery, Wearable technology.

Abstract

Trans-catheter Aortic Valve Implantation (TAVI) is an endovascular treatment for critical aortic stenosis. An early "learning curve" is important drawback of TAVI that can dramatically alter patient safety and hospital costs. There is paucity of data regarding the quantification of learning experience associated with the technique. The aim of this study was to assess learning curve in clinical staff involved in the implementation of TAVI. We hypothesize that training sessions will improve economy of movement (EoM) as characterized by measuring jerkiness of trunk movement in medial-lateral direction. Using wearable technology based on tri-axial accelerometer, the EoM of a scrub technician, who was naive to TAVI procedure, was assessed during 6 consecutive TAVI procedures, including 4 cadaver TAVI simulations and 2 clinical cases. In addition, communication errors between the surgery team were monitored. During the cadaver simulation training, the

reduced during real cases compared to the first simulated case, suggesting that cadaver simulation translated into real cases. This proof of concept study suggests that EoM could be used as an alternative method to objectively evaluate the learning curve during surgical procedures. Results should be confirmed in a larger sample size in both physicians and support staff assisting with TAVI procedure.

1. INTRODUCTION

Trans-catheter Aortic Valve Implantation (TAVI) is a minimally invasive endovascular procedure for the treatment of critical aortic stenosis [1]. It has gained acceptance in the treatment of patients who are ineligible for conventional surgical aortic valve replacement [2]. Patients who undergo TAVI benefit from superior survival and symptomatic outcomes versus patient who carry medical palliation [3, 4]. To date, more than 10000 TAVI procedures have been completed [5] and a recent study by Osnabrugge et al. reported nearly 18000 and 9200 new TAVI candidates in Europe and North America each year, respectively [6].

TAVI is a complex procedure requiring a dedicated team of cardiac surgeons, interventional cardiologists, echocardiographers and anesthesiologists [1, 7]. A careful training of TAVI team and a close collaboration between them seem to play a major role in having a successful TAVI program [1, 8].

1.1. Current training procedures and their challenges

Advanced training and experience are an important factor for success of TAVI [9]. Current TAVI training starts with theoretic procedural preparation during lecture and

familiarity the catheter system [1] and surgery on cadaver/animal is used to rehearse the required techniques for the transfemoral or transapical aortic valve implantation [13]. "Dry run" training provides an opportunity to improve communication and familiarity with new tasks [14], thereby improving team choreography [1]. Despite these potential benefits, the best metrics to assess benefit of such trainings and how they are translated to actual cases have not been validated.

Admittedly, simulations cannot replicate all aspects of an actual TAVI case, particularly many of the complications that happen in real cases such as sudden bleeding or change

in patient blood pressure. After the training phase, a number of proctored cases should be completed. Frank, open debriefings about difficult cases have proved valuable [12].

1.2. Quantification of learning during training/practices and their benefit

For evaluation of learning during TAVI training, performance measures need to be defined. Plotting performance versus experience (e.g. number of completed cases) creates a learning curve [15] and it is expected that with more experience, the performance tends to improve[16]. TAVI learning curve involves the improvement in multidisciplinary teamwork to execute a complex intervention. An early "learning curve" is an important drawback of TAVI that can dramatically alter patient safety and hospital costs[16]. Communication failures among cardiology, CT surgery and cardiac anesthesia and uncertainty about roles among support staff are common triggers for adverse events during the TAVI learning curve. In an article published recently, Block talked about the importance of learning curve in TAVI procedure [7]. The effect of training and learning curve in TAVI procedure has been evaluated in different studies [16-20]. In general, we could classify the learning curve in TAVI to two groups that try to 1) evaluate patient's outcome [18-20] and/or 2) evaluate the TAVI procedure itself [16, 17, 20].

Fluoroscopy time, valvuloplasty to valve deployment time, radiation exposure and contrast volume studied by Alli et al. during performing TAVI procedure on 44 consecutive patients [16]. Their results show that procedural time, radiation, and contrast volumes significantly decreased with increase in experience. Also, existence of plateau after the first 30 cases in their research proposed that it takes 30 cases to attain proficiency. The same parameter as Alli et al. study has been evaluated in another research on 500 consecutive high-risk patients [17]. The results of this study also confirm that operating time and radiation exposure reduced with

incidence of technical intra procedural complications have also been reported which reflects the learning curve but 30-day mortality remained unchanged [20]. Learning curve studied by Pasic et al. did not show any significant change in 30-day mortality [19].

Besides the above mentioned parameters, error in performing a technical task (e.g. improper placement of surgical device), economy of movement in navigating the required tools (e.g. path length and proportion the distance of the tool tip exceeds the optimum distance), and blood loss have also been used as learning curve in other minimally invasive surgery such as laparoscopic surgery. Furthermore, good communication and debriefing after surgery were a factor that caused a quick learning curve in minimally invasive cardiac surgery as studied by Leonard et al. [21].

In this study, we hypothesized that training and enhancing between team communications, can improve the economy of movement (EoM) in clinical staff during TAVI procedure. As a case study, we explored body motion using a wearable sensor on one clinical staff who participated in 6 consecutive cases including four training sessions and two clinical cases. Since the jerkiness of motion is an indicator of economy of motion and may be used as an indicator for the performance of human motion, it stands to reason that assessing the jerkiness of motion may be an indicator of learning effect after practices.

2. METHODS AND MATERIALS

After approval of this study by the institutional review board (IRB) in University of Arizona, physicians (two interventional cardiologists, two cardiac surgeons, cardiac anesthesiologist, and a non-invasive cardiologist) and support staff (three catheterization lab nurses and three CT surgery nurses) were recruited to participate in four cadaver TAVI simulations over a four month period followed by two clinical cases.

Each simulation and clinical case involved videotaped performance in the hybrid operating room, and a debriefing session to review case highlights. Two raters independent of the TAVI team reviewed videos for major communication errors.

Economy of movement of one clinical staff (scrub technician), who assisted in the TAVI procedure, was measured using a wearable sensor (PAMSys™, Biosensics LLC, MA, USA) inserted in a tank top shirt to assess trunk acceleration with sample frequency of 50Hz. One of the

procedure, and the data was analyzed only during TAVI procedure.

The wearable sensor allows measuring trunk acceleration in all three-body planes (e.g. sagittal, frontal and transverse). An algorithm was designed to quantify the jerkiness of body movement during TAVI procedure. In summary, the medial-lateral movement of body in frontal plane was measured by the average variation in acceleration (estimated from standard deviation of acceleration) continuously monitored by a 3 minute moving window. To remove the aberrant data,

the 5th and 95th percentiles of the measured jerkiness per trial were excluded.

Since the duration of each TAVI practice was different, except a simple real case only first 50 minutes of captured data for each trial was considered for final data analysis and between trials comparison.

Repeated measures ANOVA test was used to examine significant change in jerkiness of movement as a function of TAVI cadaver simulated practices. In addition, Student–Newman–Keuls correction was used as the post-hoc to assess pairwise comparisons between the first and the last cadaver simulated jerkiness of movement.

To characterize the early learning curve during cadaver simulations, an exponential curve ($Y=a\times\exp(-X/\tau)+b$), where ‘a’, ‘b’, and ‘τ’ are constant values and X is number of practice, was fitted to the averaged jerkiness values measured during each simulated cases. The gain and time constant resulted from simulated cases were mapped to the results obtained during real cases to explore whether the gained benefit is translated from simulated cases to real cases. In addition, to identify the magnitude of practice benefit, the jerkiness of movement in medial-lateral direction in subsequent trials were compared to the first training case experience, assuming the first case as baseline with value of 100%. Thus, a reduction in percentage of movement jerkiness is considered an enhancement in economy of motion or learning effect during TAVI procedure.

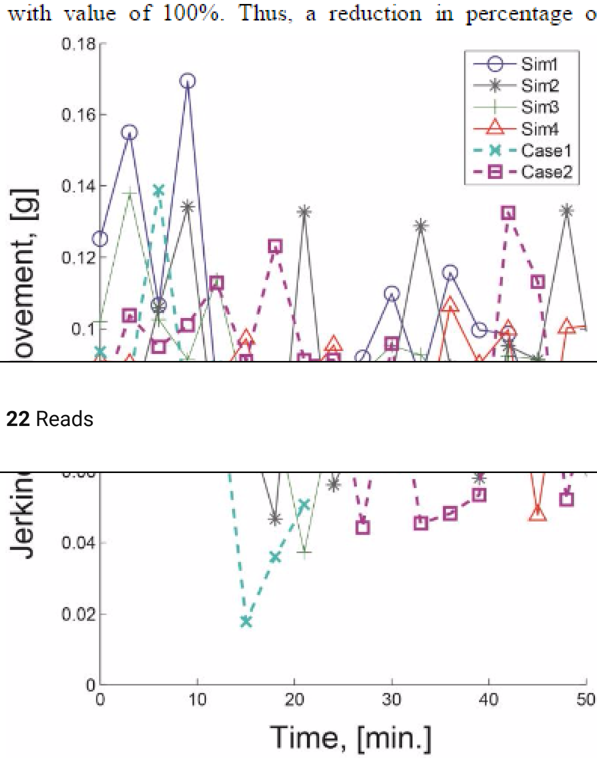

Figure 1: Jerkiness of movement for TAVI cadaver simulations and real cases.

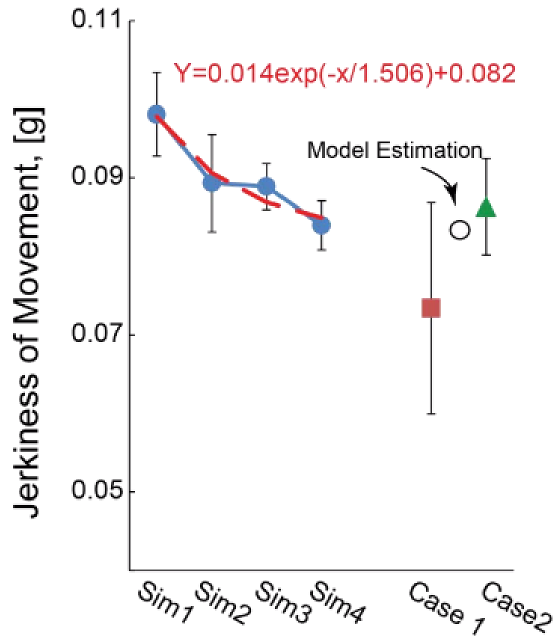

Figure 2: Jerkiness of movement is significantly reduced as a function of cadaver simulated practices in exponential fashion

3. RESULTS

The cadaver simulated trials durations ranged from 55min to 87min with an average duration of 75.5±14.0 minutes. After completing the cadaver cases, two real cases were performed, one included a simple case with duration of 25 minutes and the second one was a complex case with duration of 400 minutes.

translating into the first clinical TAVI cases (2.1 errors/case). Specifically, there was a 70% increase in the use of closed loop communication over the course of the simulations and clinical cases.

Figure 1 illustrates the jerkiness of truck movement in medial-lateral direction for all simulated and real cases. Figure 2 illustrates the changes in jerkiness of movement during simulated and real cases. The average value of jerkiness of trunk movement for the scrub tech for the first cadaver simulation was 0.098±0.021 g, which was significantly higher than the 4^{th} cadaver simulated training

age 6

age 7

OI: 10.13140/2.1.3004.4484 ·Available from: Bijan Najafi, Jan 23, 2015

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