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SHORT COMMUNICATION

Utilization of arterial pulse waveform analysis during non-cardiac surgery in Japan: a retrospective observational study using a nationwide claims database

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Abstract

Arterial pulse waveform analysis (APWA) is used for cardiac output monitoring. However, data on the frequency of and patient characteristics for specialized pressure transducer for APWA (S-APWA) use are lacking. We retrospectively identified 175,201 patients aged 18 years or older, who underwent non-cardiac surgery under general anesthesia with an arterial catheter from January 1, 2014, to December 31, 2016. We extracted data on patient demographics, comorbidities, surgical and anesthesia characteristics, and hospital characteristics. Among the full study cohort, 24,605 (14.0%) patients were monitored using S-APWA. Further, the use of S-APWA was higher in patients undergoing high-risk surgery than in those undergoing low-risk surgery [high vs low: adjusted odds ratio (aOR) 1.95; 95% confidence interval (CI) 1.76–2.15, moderate vs low: aOR 1.11; 95% CI 1.01–1.22] and those with more comorbidities than in those with less comorbidities (high vs low: aOR 1.49; 95% CI 1.42–1.56, moderate vs low: aOR 1.25; 95% CI 1.20–1.31). S-APWA use was significantly associated with both surgery risk and patients' comorbidities. In conclusion, our study may provide a benchmark for future studies related to the appropriate use of S-APWA.

Keywords Arterial pulse waveform analysis · Goal-directed therapy · FloTrac/Vigileo system · Non-cardiac surgery · Claims database

Perioperative fluid therapy is among the most controversial topics in current anesthesia practice [1]. Optimum perioperative fluid administration may improve postoperative outcome. Very little fluid administration may cause inadequate tissue perfusion, causing organ damage, whereas excessive fluid administration may cause systemic and pulmonary edema, leading to anastomosis leak and postoperative hypoxia [2, 3]. Perioperative goal-directed therapy (GDT) is used for hemodynamic optimization to ensure adequate oxygen delivery, thereby improving postoperative outcomes and reducing hospital stay duration [4]. Recently, arterial pulse waveform analysis (APWA) with a semi-invasive cardiac output (CO) monitoring device (e.g., FloTrac/Vigileo system, Edwards Lifesciences Co. [5]) has become the most common approach for CO monitoring. CO and stroke volume variation (SVV) measured using specialized pressure transducer for APWA (S-APWA) were often used for GDT [6, 7]. As mentioned previously [8, 9], SVV was commonly used as volume expansion indicator. Despite the common use of SVV and CO, there are only a few well-established protocols for fluid management and CO optimization. Furthermore, data are lacking on the frequency of and patient characteristics for S-APWA than for conventional pressure transducer. Thus, we aimed to describe the uses of those transducers in a real-world setting during non-cardiac surgery in Japan.

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This study was approved by the Institutional Review Board (Kyoto University, Japan, R1011). The requirement for informed consent was waived because of the anonymous nature of the data. This retrospective cohort study used a claims database offered by Medical Data Vision (MDV) Co., Ltd (Tokyo, Japan). In December 2016, the MDV database, used in multiple epidemiological studies [10, 11], had collected approximately 18 million patients' inpatient and claims data from 291 acute-care hospitals. This database contains both administrative claims and detailed patient data, including an anonymized patient identifier, age, sex, self-reported smoking history, diagnosis codes, prescriptions, and medical procedures. Prescriptions and medical procedures were coded using original Japanese K codes with administration and execution dates. Primary diagnosis, comorbidities, and complications were specified using the International Classification of Diseases, 10th version codes.

We selected patients aged 18 years or older who underwent non-cardiac surgery under general anesthesia with an arterial catheter between January 1, 2014 and December 31, 2016. We excluded patients who had already undergone arterial catheterization preoperatively and those with missing data on admission and discharge dates or baseline characteristic factors. If patients underwent multiple eligible surgeries, we included only the first case, because we eliminated the effects of correlation among patients. Medical claims for S-APWA (extracorporeal continuous cardiac output measurement sensor) on the day of the index surgery were used to identify S-APWA use as a primary outcome.

We examined several patient predictors of the specialized transducer, including patient demographics [age, sex, Body Mass Index (BMI), smoking history], comorbidities, surgical category, anesthesia setting such as central venous catheter (CVC) and transfusion, and years of surgery. Comorbidities were evaluated using the Quan modification of the Charlson comorbidity index (CCI), with 16 comorbidities included [12] and categorized data of modified CCI was used. Surgical type was also categorized as based on the claims codes, the surgical type was subcategorized as follows: vascular surgery, thoracic surgery, gastrointestinal surgery, neurosurgery, urology, gynecology, orthopedic surgery, head and neck surgery, and other surgeries. Surgical type was also categorized as follows: low-, moderate-, and high-risk surgeries following published guidelines [13]. Facility predictors were also examined. Anesthesia setting was classified per the annual number of general anesthesia procedures (< 1000, 1000–2000, 2000–3000 or ≥ 3000 cases). Medical institution status was classified following the bed numbers (< 200, 200–500 or ≥ 500 beds) and management body (university, public, or private hospital). We also simplified hospital characteristics into teaching and nonteaching hospitals. Teaching hospitals are hospitals with a residency program.

The predictors of S-APWA use considered in this study were patient and institutional factors described above as baseline characteristics, all of which are presented in Table 1. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for the outcome were evaluated using multivariate logistic regression analyses. The reported probability values were two-sided, and $P < 0.05$ was considered statistically significant. All statistical analyses were performed using SAS version 9.4 for Windows (SAS Institute Inc.; Cary, NC, USA).

A flow diagram for cohort identification is shown in Supplemental Figure 1. We identified 183,284 patients who underwent non-cardiac surgery with an arterial catheter under general anesthesia. Of these, 175,201 formed the full study cohort on the basis of predetermined inclusion and exclusion criteria. A total of 8083 candidate patients were excluded owing to arterial catheter placement preoperatively (2678 patients) and missing data such as admission date, discharging date, institutional data, smoking history, BMI, and emergency admission information (5405 patients). Among the full study cohort, 24,605 (14.0%) patients were monitored using S-APWA. Patient and institutional characteristics are summarized in Supplemental Table 1. At private hospitals, 19.5% (18,233/142,992) patients were monitored using S-APWA. Figure 1 shows the proportions of specialized transducer for each surgery and patient risk. Table 1 shows the aOR of patient and facility factors with S-APWA uses. Several factors, including age, sex, BMI, smoking history, emergency surgery, and year of surgery, were associated with S-APWA use; however, the aORs were relatively small. Among patient factors, S-APWA and patient risk showed significant associations (CCI scores ≥ 4: aOR 1.49; 95% CI 1.42–1.56, 2–3: aOR 1.25; 95% CI 1.20–1.31 relative to 0–1).

In terms of operative factors, there were significant associations found between S-APWA and surgical risks (high vs low: aOR 1.95; 95% CI 1.76–2.15, moderate vs low: aOR 1.11; 95% CI 1.01–1.22), anesthesia time (> 9 h: aOR 3.26; 95% CI 3.08–3.46, 6–9 h: aOR 1.67; 95% CI 1.59–1.75, 3–6 h: aOR 1.17; 95% CI 1.12–1.22 relative to < 3 h:), surgical category (vascular surgery: aOR 1.46; 95% CI 1.37–1.54, thoracic surgery: aOR 0.65; 95% CI 0.62–0.68, neurosurgery: aOR 0.37; 95% CI 0.35–0.40, head and neck surgery: aOR 0.72; 95% CI 0.64–0.80, gynecology: aOR 0.66; 95% CI 0.60–0.72, orthopedic surgery: aOR 0.91; 95% CI 0.87–0.96, other surgery: aOR 0.56; 95% CI 0.48–0.65 relative to gastrointestinal surgery), CVC (aOR 1.85; 95% CI 1.77–1.93), and transfusion (aOR 1.26; 95% CI 1.21–1.31).

Regarding institutional factors, there were significant associations found between S-APWA and annual general anesthesia cases (2000–3000: aOR 0.75; 95% CI 0.72–0.79, > 3000: aOR 0.74 95% CI 0.70–0.78, relative to < 1000 cases), teaching hospital status (aOR 0.71; 95%

Table 1 Adjusted odds ratio of patient and facility characteristics for S-APWA use

Characteristics	Adjusted OR	95% CI	*P* value
Age	1.01	1.01–1.01	< 0.0001
Sex (male)	1.07	1.03–1.11	< 0.0001
BMI	0.99	0.99–1.00	0.0023
Smoking history	1.01	0.98–1.04	0.4908
Charlson comorbidity index score			
0, 1	Reference		
2, 3	1.25	1.20–1.31	< 0.0001
4–	1.49	1.42–1.56	< 0.0001
Surgical and anesthesia factor			
Emergency surgery	0.92	0.87–0.98	0.0068
Anesthesia duration (h)			
0–3	Reference		
3–6	1.17	1.12–1.22	< 0.0001
6–9	1.67	1.59–1.75	< 0.0001
9–	3.26	3.08–3.46	< 0.0001
Central venous catheter	1.85	1.77–1.93	< 0.0001
Transfusion	1.26	1.21–1.31	< 0.0001
Surgical risk			
Low-risk of surgery	Reference		
Moderate risk of surgery	1.11	1.01–1.22	0.0333
High-risk of surgery	1.95	1.76–2.15	< 0.0001
Surgical category			
Gastrointestinal surgery	Reference		
Vascular surgery	1.46	1.37–1.54	< 0.0001
Thoracic surgery	0.65	0.62–0.68	< 0.0001
Neurosurgery	0.37	0.35–0.40	< 0.0001
Head and neck surgery	0.72	0.64–0.80	< 0.0001
Gynecology	0.66	0.60–0.72	< 0.0001
Urology	1.02	0.97–1.07	0.5302
Orthopedic surgery	0.91	0.87–0.96	< 0.0001
Other surgery	0.56	0.48–0.65	< 0.0001
Institution factors			
Cases of general anesthesia			
< 1000	Reference		
1000–2000	1.02	0.98–1.07	0.3543
2000–3000	0.75	0.72–0.79	< 0.0001
> 3000	0.74	0.70–0.78	< 0.0001
Teaching hospital	0.71	0.69–0.74	< 0.0001
Hospital management body			
Public hospital	Reference		
University hospital	1.19	1.13–1.25	< 0.0001
Private hospital	1.70	1.63–1.76	< 0.0001
Year of surgery			
2014	Reference		
2015	0.96	0.93–1.00	0.0327
2016	0.95	0.92–0.98	0.0042

BMI Body Mass Index, *CI* confidence interval, *OR* odds ratio, *S-APWA* specialized pressure transducer for arterial pulse waveform analysis

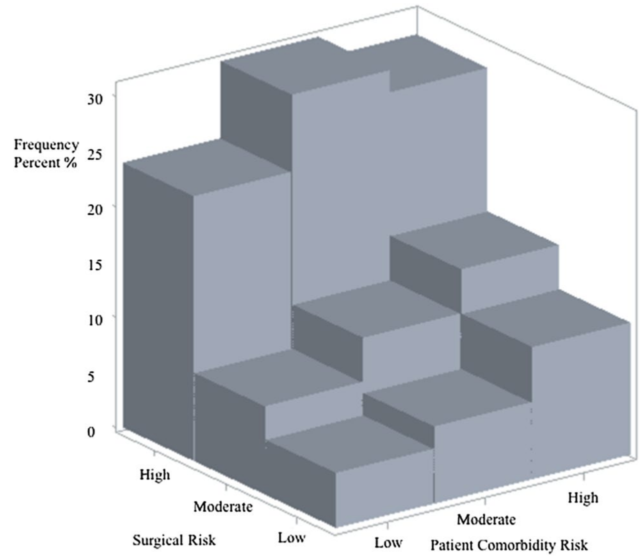

Fig. 1 The dimension model of S-APWA used showing the percentage of S-APWA in all arterial catheters. Patient comorbidity risk: high means CCI > = 4, moderate means CCI = 2 or 3, and low means CCI = 0 or 1. *CCI* Charlson Comorbidity Index, *S-APWA* specialized pressure transducer for arterial pulse waveform analysis

CI 0.69–0.74), and hospital management status (university hospital aOR 1.19; 95% CI 1.13–1.25, private hospital aOR 1.70; 95% CI 1.63–1.76 relative to public hospital).

Using a large nationwide database, we revealed that S-APWA was used in 14.0% of patients who underwent non-cardiac surgery with an arterial catheter under general anesthesia. The tendency toward S-APWA use was higher in patients with high-risk surgeries and more comorbidities as shown in Fig. 1. A questionnaire study [8] revealed that CO monitoring and SVV were commonly used as indicators of fluid loading in Japan. However, there has been no study showing the actual frequency of S-APWA use. To our knowledge, this is the first study revealing the prevalence of S-APWA use among those who underwent non-cardiac surgery with an arterial catheter under general anesthesia in real-world setting. As expected, S-APWA was used more frequently in patients with high-risk surgery than in low-risk surgery and those with more comorbidities than in those with less comorbidities. Moreover, S-APWA was also associated with hospital management status, which may vary according to the prevalence of S-APWA use. As previous health economic study showed that hospital treatment choices differ significantly by ownership type of the hospital [14], in this study, private hospitals independently showed a significant use of S-APWA compared with public hospitals. One of the reasons might be that the monitoring fee is paid on a fee-for-service basis. In this study, we are unsure whether S-APWA was used for the patients with appropriate indication and if S-APWA affected the outcome; thus, we are currently planning a future research to address these. Our study has several limitations. First, this retrospective study using an administrative database lacked clinical information, such as information on vital signs, proficiency of anesthesiologists, and number of monitoring devices, which would have been essential in deciding whether to use S-APWA. Second, the generalizability of the results to other countries with differing health insurance systems and clinical practices is limited, because SVV was more commonly used as an volume expansion indicator by Japanese anesthesiologists than by anesthesiologists in other countries [8]. Moreover, S-APWA use is also dependent on the availability of the monitoring platform such as Vigileo Monitor or LiDCO rapid; thus, if there is no such platform, S-APWA cannot be used. Especially, frequencies of S-APWA use differed between different types of hospital management status. However, we believe our research is the first step for adequate S-APWA use as it revealed the utilization of this monitor on a nationwide scale. In conclusion, S-APWA was used among 14% of patients who underwent non-cardiac surgery with an arterial catheter under general anesthesia. Frequency of S-APWA use was higher in patients with high-risk surgery and more comorbidities. Whether S-APWA is beneficial, and in what kind of patients and surgery should be examined in the future.

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