



## Hemodynamic monitoring and management of patients undergoing high-risk surgery: a survey among Chinese anesthesiologists

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### Abstract

Hemodynamic monitoring and optimization improve postoperative outcome during high-risk surgery. However, hemodynamic management practices among Chinese anesthesiologists are largely unknown. This study sought to evaluate the current intraoperative hemodynamic management practices for high-risk surgery patients in China. From September 2010 to November 2011, we surveyed anesthesiologists working in the operating rooms of 265 hospitals representing 28 Chinese provinces. All questionnaires were distributed to department chairs of anesthesiology or practicing anesthesiologists. Once completed, the 29-item questionnaires were collected and analyzed. Two hundred and 10 questionnaires from 265 hospitals in China were collected. We found that 91.4% of anesthesiologists monitored invasive arterial pressure, 82.9% monitored central venous pressure (CVP), 13.3% monitored cardiac output (CO), 10.5% monitored mixed venous saturation, and less than 2% monitored pulse pressure variation (PPV) or systolic pressure variation (SPV) during high-risk surgery. The majority (88%) of anesthesiologists relied on clinical experience as an indicator for volume expansion and more than 80% relied on blood pressure, CVP and urine output. Anesthesiologists in China do not own enough attention on hemodynamic parameters such as PPV, SPV and CO during fluid management in high-risk surgical patients. The lack of CO monitoring may be attributed largely to the limited access to technologies, the cost of the devices and the lack of education on how to use them. There is a need for improving access to these technologies as well as an opportunity to create guidelines and education for hemodynamic optimization in China.

**Keywords:** high risk surgery patients, hemodynamic management, China, fluid responsiveness

### INTRODUCTION

Despite advances that have significantly decreased anesthesia-related morbidity and mortality over the past several decades, complications following major surgery remain a substantial concern<sup>[1-3]</sup>. The risk of complications is increased in certain groups, specifically in high-risk surgical patients defined by advanced age and complex medical histories undergoing major surgery<sup>[4]</sup>.

According to *Pearse et al.*, although high-risk surgeries represent only about 12% of overall anesthetic procedures in the United Kingdom, they account for over 80% of perioperative deaths each year<sup>[2]</sup>.

In the past several decades, numerous studies have demonstrated that hemodynamic monitoring with goal-directed therapy can improve postoperative outcome, decrease the length of stay in hospital and lower the incidence of complications in high risk patients<sup>[5-15]</sup>.

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A recent meta-analysis study, published in 2011, analyzing almost thirty studies over the recent 20 year period, suggested that preemptive hemodynamic manipulation in the preoperative period reduced morbidity and mortality<sup>[16]</sup>. However, we still have not reached a point where this is an accepted standard for high risk patients in anesthesia practice.

China is the most populous country. The Chinese Ministry of Health in 2011 reported that there were estimated eighteen million major surgical procedures performed in China in 2010; of those procedures, two million patients were considered high-risk patients<sup>[17]</sup>. However, basic medical services in China are not as rich as those in North America and in Europe, and the frequency and details of hemodynamic monitoring among Chinese anesthesiologists are largely unknown. The goal of this study was to evaluate and report the current intraoperative hemodynamic management practice in patients undergoing high-risk surgery in China in order to define the potential need for education regarding hemodynamic management in this healthcare system.

## MATERIALS AND METHODS

Surveys were sent from September 2010 to November 2011 to anesthesiologists working in the operating rooms of 265 hospitals representing 28 Chinese provinces (except Taiwan and Jilin province, Tibet Autonomous Region and Inner Mongol Autonomous Region, Macao special administrative region and Hong Kong special administrative region). All questionnaires (total 265 questionnaires) were distributed directly to the department chairs of anesthesiology or practicing anesthesiologists who visited West China Hospital of Sichuan University during this time. Resident and retired anesthesiologists were excluded. Once completed, the 29-item questionnaires were collected and analyzed. The study protocol was approved by the authors' affiliated institutions.

### Survey questions

The questionnaire consisted of 29 items divided into two sections. The first section included 21 questions and assessed the current trend in hemodynamic management and monitoring for high-risk surgery in these hospitals. The second section consisted of crosscheck data concerning the anesthesiologists' personal information and practice as well as basic characteristics of the hospital. This survey has been used among North American and European anesthesiologists in a previous study<sup>[18]</sup>.

High risk surgery patients were defined below as described in previous studies<sup>[19,20]</sup>: 1. Cardiac or respiratory illness resulting in functional limitation; 2. Extensive surgery planned for carcinoma involving bowel anastomosis;

3. Predictable acute massive blood loss ( $> 2.5$  liters); 4. Aged over 70 years with functional limitation of one or more organ systems; 5. Septicemia (positive blood cultures or septic focus); 6. Respiratory failure ( $\text{PaO}_2 < 8$  kPa on  $\text{FiO}_2 > 0.4$  i.e.  $\text{PaO}_2:\text{FiO}_2$  ratio  $< 20$  kPa or ventilation  $> 48$  hours); 7. Acute abdominal catastrophe (e.g. pancreatitis, perforated viscous, gastro-intestinal bleed); 8. Acute renal failure (urea  $> 20$  mmol/L, creatinine  $> 260$   $\mu\text{mol/L}$ ); 9. Surgery for abdominal aortic aneurysm; 10. Disseminated malignancy.

### Statistical analysis

All data was entered into EpiData 3.1 (EpiData Association, Odense, Denmark). Percentages are presented with denominator (total number) and numerator (number of patients with the studied characteristic) and are rounded to the nearest one-tenth decimal place.

## RESULTS

### Anesthesiologists' descriptions

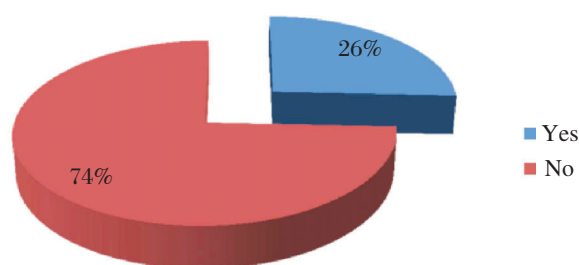
Approximately 80% (210) of the questionnaires were collected from 265 hospitals (**Table 1**). Only 189 (71.3%) questionnaires were completed. About

**Table 1 Basic characteristics of anesthesiologists and hospitals in China**

Anesthesiologists (n = 210)	
Male/female (n)	156/54
Age, years (mean $\pm$ SD)	43 $\pm$ 15
Positions	
Professor (n/%)	90/43
Associate professor (n/%)	113/54
Attending (n/%)	7/3
Work experience in anesthesiology	
$< 5$ yr (n/%)	3/1
5–10 yr (n/%)	67/32
$> 10$ yr (n/%)	140/67
Hospitals (n = 210)	
Large academic teaching hospitals and non-teaching hospitals (n/%)	97/46
Middle academic teaching hospitals and non-teaching hospitals (n/%)	113/54
Location	
North (n/%)	36/17
South (n/%)	45/21
East (n/%)	55/26
West (n/%)	74/35

\*Large academic teaching hospitals and non-teaching hospitals: more than 500 beds

\*Middle academic teaching hospitals and non-teaching hospitals: between 100 beds and 500 beds

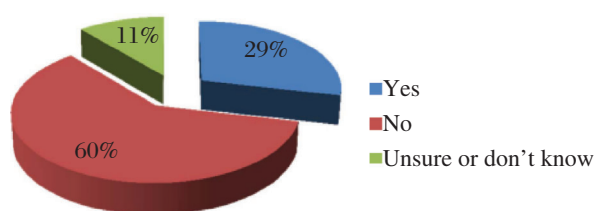


**Fig. 1** Incidence of institutional guidelines concerning hemodynamic management in this setting.

half (45.2%) of the surveyed anesthesiologists worked in academic teaching hospitals, while the other half (47.1%) worked in non-teaching hospitals. About three-quarters (75.7%) of those surveyed take care of high-risk surgical patients 1 to 5 times a week but only 10.5% do it 6 to 10 times a week. Only 11.9% of surveyed anesthesiologists take care of cardiac surgery patients. A little less than half (42.9%) had an additional one year of fellowship training: including cardiac anesthesia (15.7%), critical care medicine (12.9%), pediatric anesthesia (4.3%) and pain medicine (2.9%). In addition, 38.6% of those surveyed had finished their training after 2000 and none had finished residency before 1980. Many (39.5%) manage high risk surgery patients in the intensive care unit (**Fig. 1**). The majority (61.4%) responded work in hospitals with more than 1,000 beds, but only 38.6% of their primary hospitals have more than 40 intensive care unit beds.

### Hemodynamic monitoring and management practices

A little over a quarter (28.6%) of the hospitals have a written protocol concerning hemodynamic management in high risk surgery patients (**Fig. 2**). The following were details on hemodynamic monitoring routinely used for the management of high risk surgical patients: the majority (91.4%) monitored invasive arterial pressure, slightly less (82.9%) monitored central venous pressure (CVP), only 13.3% monitored cardiac output (CO), a small number (10.5%) monitored mixed venous saturation and less than 2% of surveyed anesthesiologists



**Fig. 2** Do you or your department/group manage these patients in the intensive care unit?

**Table 2** Hemodynamic monitoring of high risk surgery patients in China

Anesthesiologists (n = 210)	
Non invasive arterial pressure	140/66.7%
Invasive arterial pressure	192/91.4%
Central venous pressure	174/82.9%
Global end diastolic volume	6/2.9%
Transesophageal echocardiography	28/13.3%
Cardiac output	28/13.3%
Pulmonary capillary wedge pressure	24/11.4%
Venous saturation (SvO <sub>2</sub> )	22/10.5%
Mixed venous saturation (ScvO <sub>2</sub> )	30/14.3%
Near infrared spectroscopy	6/2.9%
Oxygen delivery (DO <sub>2</sub> )	14/6.7%
Pulse pressure variation or systolic pressure variation	4/1.9%
Stroke volume variation	6/2.9%

\*Results given as n/%

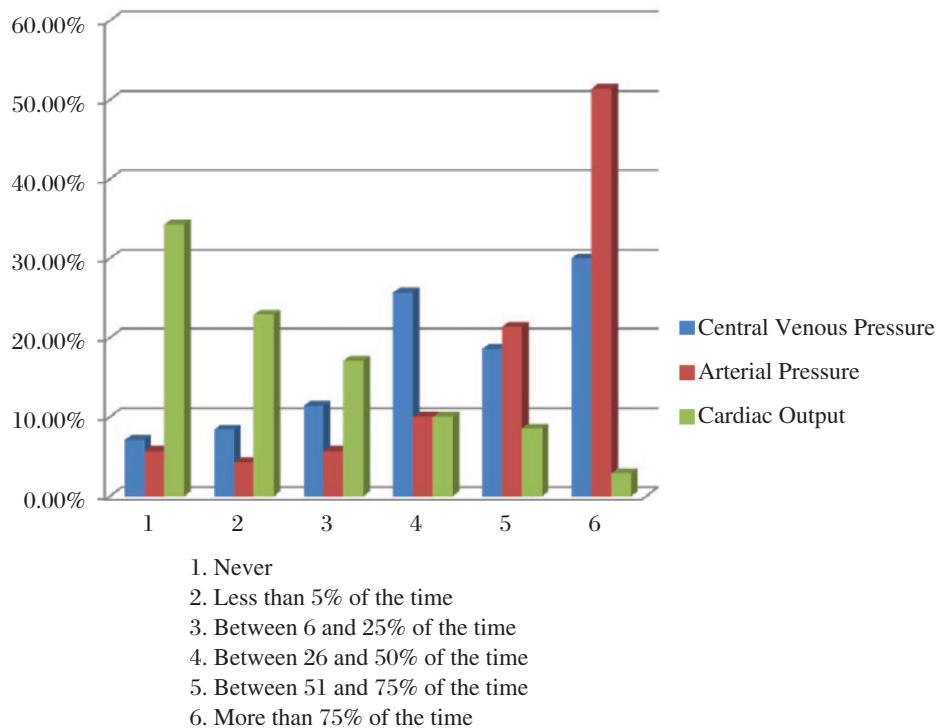
monitored pulse pressure variation (PPV) or systolic pressure variation (SPV) (**Table 2**). Invasive arterial pressure is monitored and used for hemodynamic optimization by more than 90% of those surveyed. Almost one-third (34.3%) never attempt to optimize CO intraoperatively (**Fig. 3**).

For those who do desire to have CO monitored, the Swan-Ganz catheter is the most widely used (28.1%) monitoring method in high-risk surgery patients. Transesophageal echocardiography is additionally used in this setup by 22.9% of surveyed anesthesiologists (**Table 3**). When those who do not monitor CO routinely in this patient population were asked for their reasons, the main one was that they considered the available CO monitoring solutions to be too invasive (**Table 4**). Moreover, when surveyed anesthesiologists were asked directly why they did not monitor CO in high risk surgery patients using the Vigileo monitor, LidiCO monitor or thoracic bioimpedance, almost two-thirds (31.43%) replied that such devices were not available in their hospital.

**Table 3** Technique used to monitor cardiac output

Anesthesiologists (n = 210)	
Swan Ganz catheter	59/28.1%
Esophageal doppler	8/3.8%
Vigileo monitor	3/1.4%
PiCCO monitor	36/17.1%
LiDCO monitor	3/1.4%
Thoracic bioimpedance	3/1.4%
Transesophageal echocardiography	48/22.9%
Other	2/1.0%

\*Results given as n/%



**Fig. 3** How frequently do you try to optimize central venous pressure, arterial pressure and cardiac output intraoperatively in this setting?

The majority (88.6%) of anesthesiologists relied on clinical experience as an indicator for volume expansion and more than 80% depended on blood pressure, CVP and urine output. Only 8.6% regarded CO as a commonly used indicator and 34% used CVP as a substitute for CO (**Table 5**).

Hydroxyethylstarch solution is the first line therapy used by surveyed anesthesiologists in China (65.7%) (**Fig. 4**). Almost all (94.3%) believe that oxygen delivery to the tissues is of major importance in patients during high risk surgery. When asked which parameters were involved in oxygen delivery to tis-

sues, the replies were hemoglobin (91.4%), CO (75.7%), PaO<sub>2</sub> (71.4%), SaO<sub>2</sub> (65.7%), arterial pressure (60%) and CVP (11.7%). Ninety percent of them believed that their current hemodynamic management could be improved.

## DISCUSSION

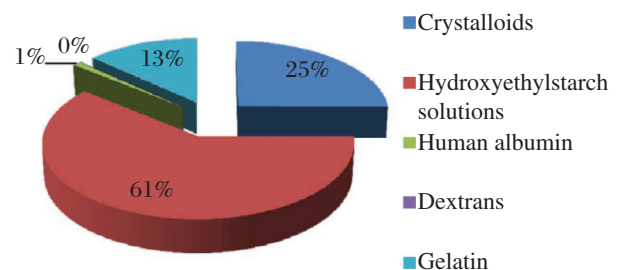
This study demonstrated that despite growing evidence supporting CO optimization for high-risk surgery patients, anesthesiologists in China who responded to this survey make very limited use of this technique in intraoperative care of their high-risk patients.

Several studies have demonstrated that CO optimization during high risk surgery has the potential to improve post-operative patient outcome (21,22) but only 13.3% of anesthesiologists in China monitor CO in this setting. Interestingly, almost all (94.3%) of sur-

**Table 4** Main reasons for not monitoring cardiac output

Anesthesiologists (n = 210)	
I use dynamic parameters of fluid responsiveness (pulse pressure variations, systolic pressure variations, plethysmographic waveform variations) as surrogates for cardiac output monitoring	51/24.3%
Available cardiac output monitoring solutions are too invasive	60/28.6%
Cardiac output monitoring does not provide any additional clinically relevant information in this setting	12/5.7%
I use SvO <sub>2</sub> and/or ScVO <sub>2</sub> as surrogates for cardiac output monitoring	30/14.3%
Available cardiac output monitoring solutions are unreliable	9/4.3%

\*Results given as n/%



**Fig. 4** Top choice for volume expansion

**Table 5 Indicators for volume expansion (diagnostic tools)**

Anesthesiologists (n = 210)	
Clinical experience	186/88.6%
Blood pressure	201/95.7%
Pulse pressure variation or systolic pressure variation	27/12.9%
Stroke volume variation	9/4.3%
Central venous pressure	180/85.7%
Global end diastolic volume	9/4.3%
Urine output	171/81.4%
Transesophageal echocardiography	18/8.6%
Cardiac output	18/8.6%
Pulmonary capillary wedge pressure	12/5.7%
Venous saturation (SvO <sub>2</sub> )	18/8.6%
Mixed venous saturation (ScvO <sub>2</sub> )	21/10.0%
Plethysmographic waveform variations	2/1.0%

\*Results given as n/%

veyed anesthesiologists agree that oxygen delivery to the tissues is of major importance in patients during high risk surgery and three-quarters (75.7%) named cardiac output as a contributor. Nonetheless, only 13.3% of anesthesiologists surveyed monitor CO which is significantly less than the 35.4% by American Society of Anesthesiologists (ASA) and 34.9% of European Society of Anaesthesiology (ESA) members<sup>[18]</sup>.

Instead of CO monitoring, the anesthesiologists rely on non-invasive arterial pressure, invasive arterial pressure and CVP for high-risk surgeries. The majority (> 80%) depend on blood pressure, CVP and urine

output as an indicator for volume expansion. This practice continues despite consistent evidence that demonstrates dramatic changes in systemic hemodynamics may not be associated with any significant changes in CVP<sup>[23–26]</sup>. It is interesting to note that 70% of anesthesiologists in the ASA and more than 64% in the ESA relied on those parameters as well as an indicator for volume expansion<sup>[18]</sup>. In fact, in this current survey, 34% of surveyed anesthesiologists continue to use CVP as a substitute for CO. Nonetheless, over 90% believed that their current hemodynamic management could be improved.

A similar survey was conducted in Europe and the United States reflecting similar trends in hemodynamic monitoring of high-risk surgical patients with a significant use of invasive arterial pressure and central venous pressure. However, the surveys returned from the ESA showed significantly more use of PPV and SVV than members of ASA; the ASA members still used these parameters more often than the respondents of the China survey (**Table 6**).

These results may be attributed to a wide array of issues, but one that stands out from the survey is the problem with limited access. The pulse contour analysis devices (such as the Vigileo or LiDCO monitors), thoracic bioimpedance and esophageal Doppler monitors are not available in about one-third of surveyed hospitals. CO optimization may be restricted by the limited availability of less invasive CO monitoring solutions in China. A similar issue was noted in the survey done between the ASA and ESA where ASA

**Table 6 Hemodynamic monitoring used for the management of high-risk surgery patients**

	ASA Respondents (n = 237)	ESA respondents (n = 195)	China respondents (n = 210)	
Answer options	Response percent			P-value
Invasive arterial pressure	95.4%	89.7%	91.4%	0.066
Central venous pressure	72.6%	83.6%	82.9%	0.007
Non-invasive arterial pressure	51.9%	53.8%	66.7%	0.003
Cardiac output	35.4%	34.9%	13.3%	0.000
Pulmonary capillary wedge pressure	30.8%	14.4%	11.4%	0.000
Tranesophageal echocardiography	28.3%	19.0%	13.3%	0.000
Systolic pressure variation	20.3%	23.6%	1.9%	0.000
Plethysmographic waveform variation	17.3%	17.9%	-----	
Pulse pressure variation	15.2%	25.6%	1.9%	0.000
Mixed venous saturation (ScvO2)	14.3%	15.9%	14.3%	0.876
Central venous saturation (SvO2)	12.7%	33.3%	10.5%	0.000
Oxygen delivery (DO2)	6.3%	14.4%	6.7%	0.008
Stroke volume variation	6.3%	21.5%	2.9%	0.000
Near infrared spectroscopy	4.6%	5.1%	2.9%	0.484
Global end diastolic volume	2.1%	8.2%	2.9%	0.006

\*Data for ASA and ESA surveys obtained from previously published work<sup>[29]</sup>



members reported limited access to monitors such as the PiCCO® and it was postulated this may be due to technologies spreading in countries where they are manufactured and developed. Although there are many factors which influence where these manufacturing companies develop their technologies, the involvement of local opinion leaders as well as marketing efforts may contribute to their presence in certain countries.

Thus, due to limited options in China, CO monitoring was done with pulmonary artery catheter placement (**Table 3**)—a phenomenon present also among the ASA members when a similar survey was performed<sup>[18]</sup>. Given that the pulmonary artery catheter is associated with high risk<sup>[27]</sup>, it may be a contributing factor to limiting CO monitoring in high-risk surgery patients. Moreover, about 70% of surveyed hospitals in China do not have clear guidelines for hemodynamic monitoring (**Fig. 3**). The uncertainty created by not having standardized recommendations about the value of perioperative hemodynamic optimization may impact use of CO monitoring in these patients

New hemodynamic parameters, PPV or SPV, require an arterial line as it is obtained from the arterial pressure waveform. Optimizing these parameters has been associated with a reduced length of hospital stay and a lower incidence of postoperative organ complications<sup>[7,25,28]</sup>. PPV, SPV and SVV are rarely used in practice for high-risk surgery patients in China (**Table 4**). Almost half (45%) of anesthesiologist depended on the PPV or SPV and 19.1% on SVV for volume expansion in ASA, while members of the ESA had a greater percentage (53.3%) depend on the PPV or SPV and 36.4% on SVV<sup>[18]</sup>. It is interesting to note 91.4% of surveyed anesthesiologists monitored invasive arterial pressure but only 12.9% monitored PPV or SPV as indicators for volume expansion in this study.

### Study limitations

As with most studies involving surveys, an ascertainment or non-response bias may be affecting our results. There were no respondents working in a private hospital and no respondents from about six provinces; this may have an impact on the accuracy of our results. However, the goal of our study is not to develop a guideline about hemodynamic monitoring and management in high risk surgery, but to evaluate and report the current intraoperative hemodynamic management practice in patients undergoing high risk surgery in China.

### CONCLUSION

We surveyed 265 anesthesiology departments and received answers from 210 departments from 28 pro-

vinces in China. The results show that most of anesthesiologists still rely on traditional hemodynamic monitoring and clinical judgement in the management of high-risk surgery patients in China. New methods of monitoring, despite recently published data validating their potential effect on morbidity and mortality, is not in widespread use. However, these parameters which can be obtained easily through minimally invasive devices are not readily available and therefore rarely used in the clinical management. Additionally, the cost of these devices may be a burden for the implementation of Goal Directed Therapy concepts in China and the lack of education on how to use the devices may add an additional barrier to their effective use. Overall, there is a definite need for improving access to these new technologies as well as an opportunity to create guidelines and education for hemodynamic optimization.

### CONFLICT OF INTEREST

Maxime Cannesson is a consultant for Edwards Lifesciences (Irvine, CA, USA), Covidien (Boulder, CO, USA), Masimo Corp. (Irvine, CA, USA), ConMed (Irvine, CA, USA), Philips Medical System (Suresnes, France), and Fresenius Kabi (Sèvres, France). Guo Chen, Yunxia Zuo and Lei Yang have no conflict of interest.

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