Study of the disparity of noninvasive and invasive blood pressure measured by the Philips Intellivue MP50 monitor in surgeries inducing gall cardiac reflex under general anesthesia

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**Objective** The aim of the present study was to comprehensively compare noninvasive and invasive blood pressure (BP) measured by the Philips Intellivue MP50 monitor in surgeries that may induce gall cardiac reflex under general anesthesia.

**Participants and methods** Seventy-eight patients undergoing cholecyst or bile duct operations under general anesthesia were enrolled in our study. Both invasive (intraradial, femoral, or dorsalis pedis artery) and noninvasive (oscillometric) BP were monitored by the Philips Intellivue MP50 monitor simultaneously. Data were analyzed using Bland–Altman plots.

**Results** In a supine position during operations, between intraradial and oscillometric measurements, the bias and precision (mmHg) were 9.34 ± 12.98 and 12.47 ± 10.00 for systolic blood pressure (SBP) and 3.26 ± 8.22 and 6.53 ± 5.97 for diastolic blood pressure (DBP), between intrafemoral and oscillometric measurements, the bias and precision (mmHg) were 14.40 ± 14.38 and 16.93 ± 11.28 for SBP and 4.35 ± 9.72 and 7.52 ± 7.54 for DBP, between intradorsalis pedis and oscillometric measurements, the bias and precision (mmHg) were 15.69 ± 14.37 and 16.91 ± 12.91 for SBP and 0.99 ± 7.69 and 5.67 ± 5.27 for DBP.

**Conclusion** The oscillometric BP showed poor agreement with intra-arterial BP in cholecyst or bile duct surgeries that may induce gall cardiac reflex under general anesthesia. Therefore, according to the present data, application of oscillometric BP measured by the Philips Intellivue MP50 monitor in these surgery patients under general anesthesia cannot be recommended generally.

**Introduction**

Gall cardiac reflex is a reflex bile duct surgery involving the gallbladder or the exploration of bile duct that causes coronary spasm and cardiac dysfunction, manifested as bradycardia or decreased blood pressure (BP), and even the occurrence of ventricular fibrillation or cardiac arrest, and other phenomena [1,2].

Accurate measurement of BP is essential for the rational hemodynamic management of surgery patients, especially for those cholecyst or bile duct operations that may induce gall cardiac reflex. BP can be measured by either invasive or noninvasive methods in surgery patients under general anesthesia. Intraradial, intrafemoral, and intradorsalis pedis artery BP measurements are the most common invasive methods used. In contrast, oscillometric BP measurement is the most common noninvasive method used during surgery. Traditionally, BP measurements by invasive methods are the gold standard and most accurately reflect the BP at any given time point. However, the placement of an arterial catheter in patients is often technically difficult, costly, and accompanied by several complications – for example, trauma, bleeding, infection, thrombosis, embolism, distal ischemia, and the formation of a pseudoaneurysm [3–6]. Although noninvasive methods are most commonly used in routine surgeries because of convenience and noninvasiveness, noninvasive blood pressure (NIBP) is less accurate and can be impacted by many factors.

However, it is unclear whether invasive and NIBP measurements could be used interchangeably in these surgeries. Therefore, in our retrospective study, we recruited 78 cases undergoing cholecyst or bile duct operations under general anesthesia whose BP, measured by the Philips Intellivue MP50 monitor, was monitored by both invasive (intraradial, intrafemoral, or intradorsalis pedis artery) and
oscillometric methods. All of these cases involved operations under general anesthesia from January 2014 to December 2016 in our hospital. We aimed to study the agreement between standard invasive and oscillometric methods undergoing cholecyst or bile duct operations.

Participants and methods

Participants

A retrospective review was performed of patients undergoing surgeries for cholecyst or bile duct whose BP was monitored by both invasive and noninvasive methods in Tongji Hospital from January 2014 to December 2016. Seventy-eight patients were enrolled in our study. The patients had an American Society of Anesthesiologists classification of 1 or 2. Patients with cardiovascular disease, high BP, or diabetes were excluded from our study.

Procedures and outcome

Measurement of noninvasive blood pressure

After transferring patients to the operating room in the supine position, they were attached to standard monitors, such as an ECG, an SpO₂ monitor, and a sphygmomanometer. The patients were administered 10 min for stabilization before measurement of NIBP (oscillometric method) from the humerus of the right arm using the Philips Intellivue MP50 monitor (Philips Medical Systems, Best, The Netherlands).

Measurement of intra-arterial blood pressure

The 78 patients with American Society of Anesthesiologists physical status 1–2 were scheduled to undergo elective surgery in Tongji Hospital. All patients who underwent elective surgeries under general anesthesia in the central operation room area were prospectively entered into this study. Entropy electrodes were applied to the right forehead of each patient and a Narcotrend monitor (MonitorTechnik, Bad Bramstedt, Germany) was used to detect whether the depth of anesthesia became insufficient at any time during the study.

After the induction of anesthesia, the same primary team placed a 20 G catheter in the radial artery at the wrist, the femoral artery at the inguinal region, or the dorsalis pedis artery at the instep. The location of intra-arterial blood pressure (IABP) was determined by the patient’s disease and surgical site. The arterial catheter was connected to a disposable pressure transducer (Edwards Life Sciences, Irvine, California, USA). The transducer was calibrated to the level of the patient’s heart, and the tubing and transducer were inspected to ensure that there were no technical issues or air bubbles that could cause erroneous recording. Then, the Philips Intellivue MP50 monitor was interfaced with the patients to enable simultaneous data collection of IABP.

After all preparations and once the hemodynamic changes stabilized, both invasive and NIBP were measured simultaneously and recorded every 5 min. To minimize the errors caused by movement and reference point changes, we selected patients who were not moved during surgery.

Ethics

The Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology, approved this study. In accordance with this approval for a retrospective analysis of patient data, no individual patient consent was required.

Statistical analysis

Data were analyzed using SPSS software (version 12.0; SPSS Inc., Chicago, Illinois, USA). Results were presented as the mean ± SD. Different invasive BP measurements and oscillometric methods were examined using Bland–Altman analysis [7].

Results

Baseline characteristics and clinical data

The clinical characteristics of the study population are summarized in Table 1. A total of 78 patients scheduled to undergo elective surgery were enrolled in our retrospective study: 17 (11 men and six women) patients with a mean age of 55 ± 14 years and a mean weight of 69 ± 14 kg were included in the intraradial group, 57 (24 men and 33 women) with a mean age of 56 ± 14 years and a mean weight of 57 ± 12 kg were included in the intrafemoral group, and four (one man and three women) with a mean age of 55 ± 9 years and a mean weight of 61 ± 10 kg were included in the intradorsalis pedis artery group.

Comparison between the intraradial and oscillometric blood pressure

The Bland–Altman analyses of systolic blood pressure (SBP) and diastolic blood pressure (DBP) between intraradial and oscillometric BP are shown in Fig. 1 and Table 2. On the basis of 755 measurements from the 17 patients, Bland–Altman analysis showed poor agreement for SBP (mean bias of 9.34 ± 12.98, with a precision of ± 2017 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.
Table 2  Bias, limits of agreement, and precision between intra-arterial blood pressure and noninvasive blood pressure for systolic blood pressure and diastolic blood pressure

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean bias ± SD</th>
<th>Upper/lower limit of agreement</th>
<th>Precision ± SD</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraradial blood pressure (mmHg)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP</td>
<td>9.34 ± 12.98</td>
<td>34.78 / -16.10</td>
<td>12.47 ± 10.00</td>
<td>755</td>
</tr>
<tr>
<td>Intrafemoral blood pressure (mmHg)</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>DBP</td>
<td>4.35 ± 8.72</td>
<td>23.40 / -14.70</td>
<td>7.52 ± 7.34</td>
<td>2566</td>
</tr>
<tr>
<td>Intradorsalis pedis blood pressure (mmHg)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP</td>
<td>15.69 ± 14.37</td>
<td>43.86 / -12.48</td>
<td>16.91 ± 12.91</td>
<td>156</td>
</tr>
<tr>
<td>DBP</td>
<td>0.99 ± 7.69</td>
<td>16.06 / -14.08</td>
<td>5.67 ± 5.27</td>
<td>156</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD.

Bias for each pair of measurements was calculated using intra-arterial blood pressure–noninvasive blood pressure and precision was calculated using the absolute difference.

DBP, diastolic blood pressure; SBP, systolic blood pressure.

12.47 ± 10.00 mmHg and DBP (mean bias of 3.26 ± 8.22, with a precision of 6.53 ± 5.97 mmHg) measured using intraradial and oscillometric methods, with limits of agreement ranging from +34.78 to −16.10 mmHg and +19.37 to −12.85 mmHg. Between the methods, 50.46% of the SBP values differed by more than 10 mmHg and 18.41% of the DBP, respectively.

Comparison between the intradorsalis pedis and oscillometric blood pressure

The Bland–Altman analyses of SBP and DBP are shown in Fig. 3 and Table 2. On the basis of 156 measurements from the four patients, between the methods, 62.82% of the SBP values differed by more than 10 mmHg and 14.10% of the DBP, respectively.

Discussion

The data from the present study showed that the noninvasive method by the Philips Intellivue MP50 monitor cannot substitute standard invasive BP measurement techniques including intraradial, intrafemoral, and intradorsalis pedis artery BP undergoing cholecyst or bile duct operations which may induce gall cardiac reflex, supporting the use of direct intra-arterial methods in monitoring and to guide treatment decisions because of their accuracy.

BP is the pressure exerted by circulating blood on the walls of the blood vessels [8]. Both invasive and noninvasive techniques reflect the effects of all fluids. However, the two techniques have intrinsic differences because they involve measurement of different quantities. For example, in the invasive measurement, the invasive BP records the sum of the lateral pressure (measured by the NIBP) and the converted kinetic energy. In most patients, SBP increases significantly moving from the aorta out to the periphery, primarily because of wave reflection. DBP changes to a lesser extent and decreases peripherally. Because of this, the invasive and noninvasive methods of measurement and the different sites of BP are different [9,10].

The Philips Intellivue MP50 monitor used in our hospital provides noninvasive near-continuous BP monitoring and is designed to be an alternative to direct IABP measurement.

Fig. 1

Comparison between the intraradial and oscillometric blood pressure. (a, b). Bland–Altman plot between systolic blood pressure (SBP), diastolic blood pressure (DBP) estimated by intraradial and SBP, DBP measured by the oscillometric method. Solid line: mean; dashed lines: ± 1.96 SD.
By compressing the artery with a cuff and then slowly releasing pressure, pulsations from the artery are transmitted as oscillations to the cuff, with SBP and DBP recorded. In our hospital, the Philips Intellivue MP50 monitor is used to monitor NIBP and IABP of surgery patients in the operating room. However, there is little information on the agreement about NIBP and IABP in surgeries inducing gall cardiac reflex under general anesthesia.

Gall heart reflex was first proposed by Babcock in 1909 and because of the high incidence of bile duct, gallbladder, and pancreatitis disease, gall cardiac reflex is not uncommon in clinical. Accurate measurement of BP is crucial for surgeons and anesthesiologists to monitor the hemodynamic change in these surgery patients who have a high incidence of gall heart reflex. Inaccurate measurement of arterial BP can lead to inappropriate interventions.

Traditionally, BP measurements by invasive methods are the gold standard and most accurately reflect the BP at any given time point. Thus, in our study, three different IABPs were used to calibrate the oscillometric device. In our study, we compared different IABP locations (intraradial, intrafemoral, and intradorsalis pedis) with the oscillometric method from the humerus of the right arm during anesthesia with the patient in the supine position undergoing cholecyst or bile duct operations. It was found that there was clinically poor agreement between the direct BP (including intraradial, intrafemoral, and intradorsalis pedis) and oscillometric BP for both SBP and DBP measured by Philips Intellivue MP50. Our data suggested that although the mean bias and precision of DBP between IABP and NIBP was within the minimum performance standard set by the Association for the Advancement of Medical Instrumentation with the recommendation that NIBP devices be accurate within 5 mmHg and have a precision within 8 mmHg, the results also showed that among all the methods, more than 10% of the arterial BP values of SBP and DBP differed by more than 10 mmHg, which was without the standards proposed by the Association of the Advancement of Medicine.

Fig. 2
Comparison between the intrafemoral and oscillometric blood pressure. (a, b). Bland–Altman plot between systolic blood pressure (SBP), diastolic blood pressure (DBP) estimated by intrafemoral and SBP, DBP measured by the oscillometric method. Solid line: mean; dashed lines: ± 1.96 SD.

Fig. 3
Comparison between the intradorsalis pedis and oscillometric blood pressure. (a, b). Bland–Altman plot between systolic blood pressure (SBP), diastolic blood pressure (DBP) estimated by intradorsalis pedis and SBP, DBP measured by the oscillometric method. Solid line: mean; dashed lines: ± 1.96 SD.
Medical Instrumentation [11]. In addition, clinical and therapeutic decision-making is affected by the calculated SDs of ±12.98, ±8.22, ±14.38, ±9.27, ±14.37, and ±7.69 mmHg determined by the oscillometric method. These inaccuracies could lead to unnecessary interventions or lack of appropriate interventions in anesthetic management.

A possible explanation for the difference observed might be because the oscillometric method is not standardized; measuring algorithms differ from manufacturer to manufacturer and even from device to device. Cerejo et al. [12] studied two species-specific oscillometric BP monitors (petMAPclassic and petMAPgraphic) and found that these two monitors provide unacceptable SBP estimations; however, MAP values derived from both monitors and DBP measured by the petMAPgraphic resulted in acceptable agreement compared with IABP. Belani et al. [13] reported a good agreement between the Vasotrac (a device that uses frequent gentle compression and decompression of the radial artery at the wrist) and IABP measurements in a study of 80 surgical and critically ill patients placed in the supine position with a bias and precision of 0.0±5.4 and 3.9±3.7 for SBP and −0.4±3.9 and 2.7±2.8 for DBP. Also, a good agreement was found between the T-Line Tensymeter (continuous NIBP management device) BP and IABP in surgery patients [14]. However, Mireles et al. [15] reported that a poor correlation exists between oscillometric and radial arterial BP as measured by the Philips MP90 monitor in 11 adult patients on the neurosurgical service.

Some limitations of our study need to be mentioned. First, only a small number of patients were included in the intraradial and intradorsalis pedis artery groups, especially the intradorsalis pedis artery group, which may have affected our results. Second, no study has reported the validation of the Philips Intellivue MP50 monitor used in our hospital according to a recognized protocol and further studies are still needed. Third, in our study, NIBP of all the 78 patients was recorded from the humerus of the right arm. There are no comparisons between NIBP of the thigh, ankle, and IABP. One reason is that in most hospitals, NIBP of most patients was recorded from the arm because of its practicality and simplicity, and in only a few patients NIBP was recorded from the thigh and ankle because of specific reasons, for example, arm diseases. Another reason is that NIBP of the arm measured by the oscillometric method has quite a good agreement with IABP, whereas agreement of NIBP for the thigh and ankle with the invasive reference was less enthusiastic [16]. Thus, in our study, comparing NIBP with IABP, we measured NIBP from the arm rather than the thigh and ankle.

Conclusion
Although used widely, the oscillometric method of BP measured by the Philips Intellivue MP50 monitor was inaccurate in patients undergoing cholecyst or bile duct operations that may induce gall cardiac reflex under general anesthesia, and the parameters obtained should be used with caution. Therefore, the findings from the present study using the oscillometric method monitoring system in this subset of surgery patients under general anesthesia suggest that this technique cannot be recommended generally. Whether such a tool might be reliable in certain ill patients remains to be determined.

Acknowledgements
Conflicts of interest
There are no conflicts of interest.

References

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