Advantages of Continuous Noninvasive Blood Pressure Monitoring

IOH in Low-risk & ASC Patients

IOH and Patient Harm

BP Arm Cuff Inadequacies

Consensus Statement Review

BD Finger Cuffs Compared to Arterial Lines

Arterial Line Costs and Complications

Intraoperative hypotension is common in low-risk patients and care settings

Intraoperative hypotension (IOH) is common in a variety of clinical settings. Multiple large studies describe the incidence of IOH as ranging from 18% to 88% in patients undergoing noncardiac surgery when IOH was defined as a mean arterial pressure (MAP) of less than 65 mm Hg.[1-3] With most of this information coming from academic hospitals, another study recently examined the incidence of IOH in a sample of more than 127,000 cases from 45 community practice settings across the United States, and reported the incidence of IOH to be 29% when defined as a MAP of less than 65 mm Hg for at least 15 minutes, cumulatively (Table).[4] This definition was based on the IOH quality measure established by the Centers for Medicare & Medicaid Services Merit-based Incentive Payment System program.[4] The study's investigators were surprised to find that the incidence of IOH in community settings aligned with rates found in academic hospitals because they presumed patients in these settings were lower risk and would thus experience less IOH.[4] Instead, the data showed that IOH was slightly more common in patients who were younger (18-39 years of age), healthier (ASA II vs ASA III or IV) and undergoing procedures in ambulatory surgery centers (ASCs)—all typically considered low risk.[4] Additionally, the incidence of IOH varied widely across clinicians, suggesting that IOH is a modifiable risk factor to target for quality improvement.[4]

With more complex surgeries being performed in ASCs, another study by the same group investigated IOH incidence in more than 16,000 patients across 20 ASCs in the United States.[5] Similarly, they found that IOH (MAP < 65 mm Hg for ≥15 minutes) was present in approximately 31% of ASC cases.[5] Patients typically considered low risk had higher incidence of IOH including those who were younger (18-39 years of age), healthier (ASA II vs ASA III or IV) and undergoing less complex (compared with moderately complex) procedures.[5] IOH was also high in longer and high-complexity procedures.[5] Again, the study's investigators felt this was a higher-than-expected incidence of IOH given a seemingly low-risk patient population, suggesting it is important to improve monitoring of IOH in ASC settings.[5]

The evidence suggests a strong association between IOH and patient harm

Preventing IOH is particularly important as it is associated with several adverse patient outcomes. According to a Perioperative Quality Initiative (POQI)-3 consensus statement, IOH (MAP <60-70 mm Hg) is associated with acute kidney injury, myocardial injury, and death with injury being a function of IOH severity and duration.[6] Associations have also been found between IOH and postoperative cognitive dysfunction, delirium, stroke, surgical site infections, and longer post-anesthesia care unit (PACU) stays.[7-9] Additionally, a large multicenter, retrospective cohort study (N=368,222) found IOH to be associated with 30-day major adverse cardiac or cerebrovascular events during noncardiac surgery, with associations magnified with increasing hypotension severity.[1] The investigators concluded that IOH is a serious public health issue affecting all age groups and should not be ignored.[1]

Additionally, the Anesthesia Patient Safety Foundation's (APSF) 2024 consensus recommendations identified hemodynamic instability as a patient safety issue that should be addressed to prevent harm.[10] While hemodynamic instability is a complex syndrome that involves many physiologic parameters, current clinical practice focuses on treating blood pressure as a surrogate of hemodynamic instability.[10] Thus, the APSF recommendations reinforce the need to reduce the burden of hypotension in surgical patients, as evidence suggests a strong association with patient harm.[1,10]

Standard blood pressure cuffs may not accurately detect hypotension

The oscillometric noninvasive blood pressure arm cuff is commonly used in perioperative settings but has notable limitations in its ability to detect hypotension accurately and reliably. For instance, oscillometric monitoring performs reasonably well when actual MAP is approximately 75 mm Hg, but its accuracy decreases when hypotension or hypertension are present.[11,12] Oscillometry can also overestimate low arterial pressures, potentially missing hypotension.[12-14] Additionally, manufacturers of oscillometric cuff technologies rely on different proprietary algorithms to assess blood pressure, leading to wide variability in agreement compared with invasive measurements.[15] Studies have found statistically and clinically significant differences between oscillometric cuffs and invasive measurements with an arterial line (the gold standard for blood pressure measurement), suggesting that oscillometric cuffs are not as accurate.[12,16,17] One study that analyzed more than 2.8 million pairs of blood pressure measurements from over 38,000 patients found the oscillometric cuff misclassified 50% of MAP values lower than 65 mm Hg when compared with invasive measurements.[17] Additionally, the oscillometric cuff is not as reliable in patients with atrial fibrillation[18] or obesity.[19] Oscillometric cuffs that are not appropriately sized to the patient can lead to inaccurate measurements.[15,20] In addition to improper sizing, arm shape can also lead to inaccurate blood pressure measurements in obese patients when the arm becomes cone-shaped (ie, the circumference of the upper arm is greater than the lower arm).[19,21,22] Here, the rectangular-shaped cuff may overestimate blood pressure.[22] Lastly, some surgical patients may need an oscillometric cuff placed somewhere other than the upper arm due to intraoperative patient positioning. While the ankle has been proposed as an alternative, oscillometric ankle measurements are also inaccurate compared with an arterial line.[23]

Continuous versus intermittent monitoring is more effective in reducing IOH

Another limitation of the oscillometric cuff is that it measures blood pressure intermittently every few minutes and may naturally miss some instances of IOH.[24] BD offers a portfolio of noninvasive finger cuffs (Acumen IQ™ Finger Cuff, ClearSight™ Finger Cuff, VitaWave™ Finger Cuff) that continuously monitor a patient's blood pressure. These technologies have the potential to more effectively reduce IOH in patients when compared with an oscillometric cuff. For example, those monitored intermittently with an oscillometric cuff had more missed and delayed recognition of hypotensive events than those monitored continuously with ClearSight Finger Cuff.[24] Another study found that those monitored intermittently with an oscillometric cuff experienced more severe hypotensive events (MAP <55 mm Hg) than those with continuous ClearSight Finger Cuff monitoring.[25] Furthermore, patients who received continuous monitoring with ClearSight Finger Cuff have repeatedly been shown to experience less IOH than those monitored with an oscillometric cuff.[25-27] Specifically, the DETECT trial found that IOH was 90% lower during surgery and 60% lower during induction of anesthesia in those receiving continuous monitoring with ClearSight Finger Cuff versus intermittent oscillometric monitoring,[27] while another randomized trial found that continuous monitoring with ClearSight Finger Cuff nearly halved the amount of IOH compared with an oscillometric cuff.[26] A large systematic review (N=46,377) confirmed that there was moderate- to high-quality evidence that continuous noninvasive monitoring reduced IOH compared with intermittent oscillometric monitoring.[28]

Consensus recommendations recognize importance of continuous monitoring

Several consensus statements from professional medical societies highlight the need for continuous monitoring. The APSF's consensus recommendations for perioperative patients with hemodynamic instability recommend implementing continuous noninvasive monitoring since it may detect hypotension earlier than traditional monitoring.[10] The POQI-11 international consensus statement on perioperative arterial pressure management recommends clinicians consider continuous blood pressure monitoring as it can help reduce severity and duration of IOH compared with intermittent monitoring.[29] These recommendations emphasize there is strong evidence that continuous monitoring allows clinicians to intervene early and effectively, substantially reducing IOH.[29] Similarly, the German Society of Anaesthesiology and Intensive Care Medicine also released guidelines that strongly recommend continuous blood pressure monitoring for all patients at risk for complications associated with hypotension.[30]

BD continuous blood pressure monitoring is accurate when compared to invasive monitoring

BD's continuous noninvasive finger cuffs meet equivalency by FDA standards for accuracy compared to a radial arterial line for measuring blood pressure.[31] Several validation studies confirm its accuracy in a variety of patient populations, such as those undergoing noncardiac,[32] cardiac,[33] transcatheter aortic valve replacement,[34,35] bariatric,[36] atrial fibrillation ablation,[37] cesarean delivery,[38] and shoulder[39] procedures as well as those in the ICU.[40] Because oscillometric cuffs have limitations in obese patients and those with atrial fibrillation, it is particularly notable that ClearSight Finger Cuff showed comparable accuracy to a radial arterial line in both of these populations.[36,37,41] In obese patients, ClearSight Finger Cuff specifically had better agreement with an arterial line for MAP and diastolic blood pressure compared with oscillometric measurements.[19]

Invasive methods may be costly and are associated with complications

Placement of an arterial line requires additional equipment, such as a transducer kit, pressure tubing, IV fluid, pressure bag, insertion needle and guidewire, drape, sterile dressing and gloves, cleaning solution, local anesthetic with needle and syringe, gauze, and suture material,[42,43] which may contribute to burdens on time and costs as well as medical waste. Arterial lines have been associated with increased length of stay[44] and their placement may result in increased costly complications such as access site hematomas, bleeding, infections, occlusion, thrombosis, and dislodgement.[45,46] Although uncommon, complications such as hematomas and bleeding can be costly, with hospital costs estimated to range from $3,700 to $6,300 per event.[45,47-49] Additional potential costs associated with placement of arterial lines include opportunity costs (ie, increased operating times with the use of a less efficient technology) compared with an alternative.[50] One study examined such costs and found that placement of an arterial line at the beginning of neuroendovascular procedures was associated with procedure start time delays,[51] while another found that arterial line placement was associated with additional preincision time and increased cost per case.[52] Considering these opportunity costs, the average cost of a radial arterial line can range from $743 to $1,171.[51] Furthermore, placement of noninvasive blood pressure monitoring is much faster than an arterial line and requires minimal setup. Studies found that continuous noninvasive monitoring with ClearSight Finger Cuff significantly reduced procedural time compared with arterial lines, with the average amount of time saved per case ranging from 19 to 52 minutes.[45,53-55] Removal of an arterial catheter also requires additional resources, such as an occlusion device or a staff member to apply pressure at the insertion site. Thus, omitting invasive monitoring could lead to shorter procedure and lab turnover time.[45] Postoperatively, patients who experience deterioration may require unplanned interventions or procedures, such as rapid response team activation or ICU transfer, contributing to increased costs and length of stay.[56-59] This suggests that early detection of deterioration by continuously monitoring vital signs, such as blood pressure, is of utmost importance,[56] especially considering that hypotension has been shown to be the most common trigger for medical emergency team activation postoperatively.[60] A cost-savings analysis found that implementing continuous monitoring technologies in medical-surgical units would result in significant hospital cost savings.[56] Additionally, advanced recovery room care (ie, an extended PACU) that included continuous noninvasive monitoring allowed for earlier detection of medical emergency response events during the first 24 postoperative hours compared with standard ward care.[61] This care was also associated with less complications after the first 24 hours, decreased emergency department visits, and increased days at home at 30 days.[61] The investigators also suggested that early efforts to reduce hypotension may have contributed to the decrease in medical emergency response events and low rate of ICU referral.[61] A separate analysis found that this advanced recovery room care could also be highly cost-effective, decreasing overall hospital costs per patient.[62]

Conclusion

IOH is common in a variety of settings, even in patients typically considered low risk. Professional medical societies are increasingly reinforcing the need to reduce the burden of IOH, as it is strongly associated with patient harm. Oscillometric blood pressure monitoring does not meet the needs of all patients as it is intermittent, less accurate in certain patient populations, and less effective at detecting blood pressure extremes. Continuous noninvasive blood pressure monitoring by BD offers comparable accuracy to a radial arterial line and is a viable option for patients who do not otherwise need an invasive arterial line.

Information contained in this document is based on the following references:

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Appendix A.

Table 1. Incidence of IOH in Top Anesthesia Procedure Codes in Community Anesthesia Practices

Anesthesia Procedure Code	Procedure Description	MAP <65mmHg for 15+ min	Number of Cases
00840	Anesthesia for intraperitoneal procedures in lower abdomen including laparoscopy; not otherwise specified	25.2%	10,532
00790	Anesthesia for intraperitoneal procedures in upper abdomen including laparoscopy; not otherwise specified	23.0%	9,931
00400	Anesthesia for procedures on the integumentary system on the extremities, anterior trunk and perineum; not otherwise specified	29.8%	7,723
00670	Anesthesia for extensive spine and spinal cord procedures (e.g., spinal instrumentation or vascular procedures)	36.5%	7,013
01480	Anesthesia for open procedures on bones of lower leg, ankle and foot; not otherwise specified	30.2%	6,304
00300	Anesthesia for all procedures on the integumentary system, muscles and nerves of head, neck and posterior trunk, not otherwise specified	35.6%	4,146
01402	Anesthesia for open or surgical arthroscopic procedures on knee joint; total knee arthroplasty	34.5%	4,144
01400	Anesthesia for open or surgical arthroscopic procedures on knee joint; not otherwise specified	17,4%	3,925
01630	Anesthesia for open or surgical arthroscopic procedures on humeral head and neck, sternoclavicular joint, acromioclavicular joint and shoulder joint; not otherwise specified	27.8%	3,706
01810	Anesthesia for all procedures on nerves, muscles, tendons, fascia and bursae of forearm, wrist and hand	16.9%	3,570

IOH, intraoperative hypotension; **MAP,** mean arterial pressure. Based on reference 4.

Table 2.

Most Common Anesthesia Procedure Codes for Procedures Lasting 3 or More Hours in Ambulatory Surgery Centers

Anesthesia Procedure Code	Procedure Description
00402	Anesthesia for procedures on the integumentary system on the extremities, anterior trunk and perineum; reconstructive procedures on breast (e.g., reduction or augmentation mammoplasty, muscle flaps)
00300	Anesthesia for all procedures on the integumentary system, muscles and nerves of head, neck and posterior trunk, not otherwise specified
00802	Anesthesia for procedures on lower anterior abdominal wall; panniculectomy
00670	Anesthesia for extensive spine and spinal cord procedures (e.g., spinal instrumentation or vascular procedures)
00400	Anesthesia for procedures on the integumentary system on the extremities, anterior trunk and perineum; not otherwise specified
01480	Anesthesia for open procedures on bones of lower leg, ankle and foot; not otherwise specified
00103	Anesthesia for reconstructive procedures of eyelid (e.g., blepharoplasty, ptosis surgery)
01630	Anesthesia for open or surgical arthroscopic procedures on humeral head and neck, sternoclavicular joint, acromioclavicular joint and shoulder joint; not otherwise specified
01830	Anesthesia for open or surgical arthroscopic/endoscopic procedures on distal radius, distal ulna, wrist, or hand joints; not otherwise specified
00160	Anesthesia for procedures on nose and accessory sinuses; not otherwise specified

Based on reference 5.