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Incidence of Intraoperative Hypotension as a Function of the Chosen Definition

Literature Definitions Applied to a Retrospective Cohort Using Automated Data Collection

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Background: **Intraoperative hypotension (IOH) is a common side effect of general anesthesia and has been reported to be associated with adverse perioperative outcomes. These associations were found using different definitions for IOH. It is unknown whether the incidences of IOH found with those different definitions are comparable. The authors aimed to describe the relation between the chosen definition and incidence of IOH.**

Methods: **First, a systematic literature search was performed to identify recent definitions of IOH that have been used in the anesthesia literature. Subsequently, these definitions were applied to a cohort of 15,509 consecutive adult patients undergoing noncardiac surgery during general anesthesia. The incidence of IOH according to the different threshold values was calculated, and the effect of a defined minimal duration of a hypotensive episode was studied.**

Results: **Many different definitions of IOH were found. When applied to a cohort of patients, these different definitions resulted in different IOH incidences. Any episode of systolic blood pressure below 80 mmHg was found in 41% of the patients, whereas 93% of the patients had at least one episode of systolic blood pressure more than 20% below baseline. Both definitions are frequently used in the literature. The relation between threshold values from the literature and IOH incidence shows an S-shaped cumulative incidence curve, with occurrence frequencies of IOH varying from 5% to 99%.**

Conclusions: **There is no widely accepted definition of IOH. With varying definitions, many different incidences can be reproduced. This might have implications for previously described associations between IOH and adverse outcomes.**

This article is accompanied by an Editorial View. Please see: Warner MA, Monk TG: The impact of lack of standardized definitions on the specialty. ANESTHESIOLOGY 2007; 107:198–9.

Additional material related to this article can be found on the ANESTHESIOLOGY Web site. Go to http://www.anesthesiology.org, click on Enhancements Index, and then scroll down to find the appropriate article and link. Supplementary material can also be accessed on the Web by clicking on the "ArticlePlus" link either in the Table of Contents or at the top of the Abstract or HTML version of the article.

INTRAOPERATIVE hypotension (IOH) is a common and frequent side effect of anesthesia.[1,2] Previously, IOH was reported to be independently associated with adverse perioperative outcomes in several clinical settings, and even an association between IOH and long-term (1-year) mortality was reported.[3–7] These findings have important clinical and medicolegal consequences. Perioperative stroke, for example, has often been attributed to IOH,[8–11] although Limburg *et al.*[12] were unable to find an association between IOH and postoperative stroke. Furthermore, IOH was recently reported to be one of the most important concerns associated with the occurrence of postoperative myocardial ischemia and infarction.[13]

Studies that reported an association between IOH and adverse outcomes have used very different definitions of IOH. Some authors defined IOH as a decrease in systolic or mean blood pressure below a certain absolute threshold,[4] whereas others have used a decrease in blood pressure relative to the patients' baseline blood pressure.[14] Combinations of definitions including the duration of a decreased blood pressure have been used as well.[3] Even particular therapeutic actions of the attending anesthesiologist have been included in IOH definitions, such as administering fluids or a vasopressor.[1,2,15,16] Finally, and probably more confusing, is the use of different definitions of IOH by the same authors in subsequent publications, or the use of a different definition of IOH depending on the type of surgery.[17–19]

It seems evident that the incidence of IOH will depend on the chosen definition, although this has not been formally studied. We therefore hypothesized that different definitions of IOH will result in different incidences of IOH. We first performed a systematic literature search to identify the range of definitions of IOH that are used in the anesthesiology literature. Subsequently, these definitions were applied to a large cohort of patients to study the differences in observed frequencies of IOH across these definitions.

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Materials and Methods

Study Design

This study included a systematic literature search, followed by an observational, retrospective cohort study. This cohort analysis included adult patients who had undergone noncardiac surgery at the University Medical Center Utrecht (The Netherlands). The study protocol was approved by the hospital ethics committee. Because patients were not submitted to investigational actions but treated with usual care and the current study only documented the routinely gathered patient data, there was no need for written informed consent.

Part 1: Systematic Literature Search

A systematic PubMed/MEDLINE search over the period January 2000 to April 2006 was performed using only the term "hypotension." Because we were mainly interested in the definition of IOH as used by anesthesiologists, the search was restricted to the four anesthesiology journals with the highest impact factor (IF) in 2004 (Institute for Scientific Information, Journal Citation Reports, 2004) and excluding pain journals. The selected journals were ANESTHESIOLOGY (IF = 4.1), *British Journal of Anaesthesia* (IF = 2.5), *Anesthesia & Analgesia* (IF = 2.2), and *Anaesthesia* (IF = 2.2). Pediatric and animal studies, case reports, comments, and letters to the editor were excluded because they seldom contained a definition of IOH. Articles studying hypotension exclusively in the postoperative period were excluded as well.

The selected articles were screened for the presence of a definition of IOH (J.B.B.). Criteria on which rescue treatment was given for low blood pressure were interpreted as a definition of IOH. When decreases in blood pressures were observed in a well-defined study period (*e.g.*, maximal decrease in systolic blood pressure > 20% from the baseline value within 80 min after induction of epidural anesthesia[20]), this time period was not interpreted as part of the definition of IOH. A second independent reviewer (T.H.K.) also screened the selected articles on the definition of IOH. When there was any inconsistency among the two reviewers, consensus was achieved using a third independent reviewer (W.A.v.K.). The found definitions of IOH were used for further analysis in part 2 of the current study.

Part 2: Cohort Study

Patients. The study included all consecutive adult patients (aged 18 yr or older) undergoing noncardiac surgery during general anesthesia at the University Medical Center Utrecht between January 1, 2004, and January 1, 2006. Procedures performed during local or regional anesthesia (including peripheral blockades) and nonsurgical procedures performed in the operating room (*e.g.*, electroconvulsive therapy or cardioversion) were excluded. Patients for whom no baseline blood pressure could be calculated were also excluded.

Data Collection and Extraction. Data were obtained from an electronic anesthesia record-keeping (ARK) system. This ARK system stores data from the anesthesia ventilator and monitor (such as ventilator settings, blood pressure, heart rate, and oxygen saturation) every 60 s as well as data that are entered manually during anesthesia (such as administration of medications, time of intubation, and infusions). In general, noninvasive blood pressure was measured at least every 5 min, and the most recent values from the anesthesia monitor from both noninvasive and invasive blood pressure were stored every minute where available.

When both noninvasive and invasive blood pressures were measured, invasive blood pressure measurements were used instead of noninvasive measurements.

The found definitions of IOH in part 1 used both absolute thresholds and thresholds relative to a baseline blood pressure. For IOH definitions using a blood pressure threshold relative to a baseline, the baseline was defined as the mean of all available blood pressure measurements before induction of anesthesia. This implies, of course, that at least one blood pressure measurement is available before the induction of anesthesia. This in turn, obviously requires the availability of the exact time of induction. In our ARK system, however, induction time is entered manually, often after all induction and intubation actions are completed. Therefore, we considered it to be a less reliable estimate of the exact time of induction. To give a more precise estimate of the time of induction, we developed an algorithm using LabView software (version 8; National Instruments Corporation, Austin, TX). The algorithm defined the time of induction as either the moment of administration of induction agents or 3 min before the first appearance of continuous expired carbon dioxide registration, whichever came first. In this, it was assumed that the expired carbon dioxide detection was a proxy for (manually) ventilating the patient, and that the induction medication was administered. Although it is routine practice that at least one blood pressure measurement is taken before induction of anesthesia, it is possible that using the aforementioned algorithm, no blood pressure measurement could be found before the estimated time of induction (*e.g.*, when intravenous induction was performed immediately after the first blood pressure measurement). These cases were excluded from the analysis.

Analysis. The analysis was performed using the aforementioned LabView program. For each patient, this program retrieved patient characteristics and a data array containing all blood pressure data from the ARK system. We calculated per patient the estimated time of induction and the baseline blood pressure. For each threshold from the used IOH definitions, absolute (mmHg) or relative to the calculated baseline (%), we calculated per patient the number and duration of IOH episodes. All analyses were repeated using time variables of 5 and 10

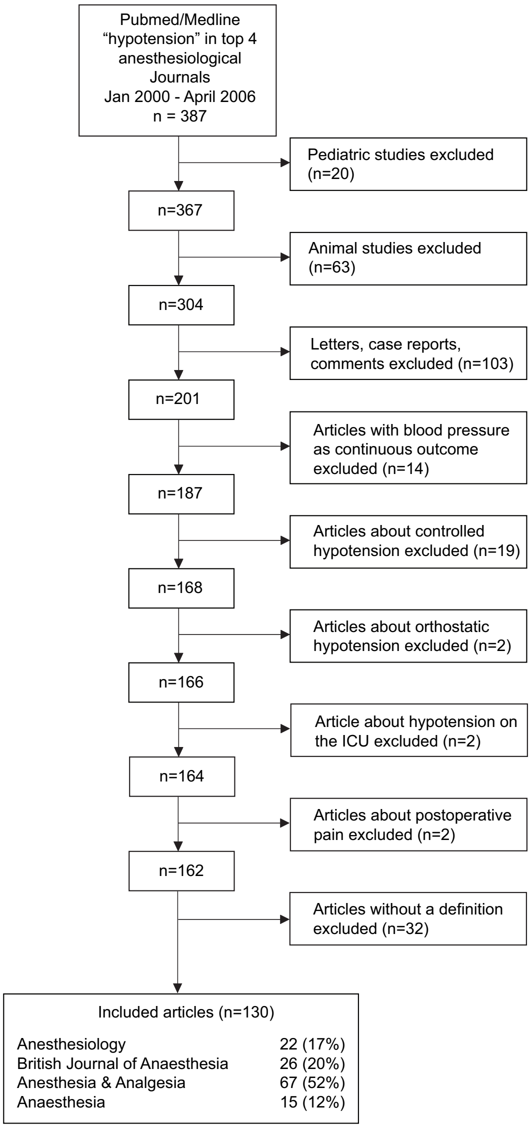

Fig. 1. Schematic representation of the systematic literature search.

min for the minimal episode of IOH duration, according to the definitions used in the literature. Finally, for every IOH definition, the overall incidence of IOH (in the total cohort) was calculated using SPSS (release 12.0.1; SPSS Inc., Chicago, IL).

Results

Part 1: Literature Search

The literature search resulted in 387 articles in the four selected anesthesiology journals. After application of the inclusion and exclusion criteria, 130 articles providing 140 definitions of IOH remained (fig. 1). The reviewers agreed on 111 articles, and on 19 articles the third reviewer achieved consensus. The results of the systematic literature search are presented in Web table 1, which is available on the ANESTHESIOLOGY Web site at http://www.anesthesiology.org. All definitions of IOH (table 1) were based on either systolic or mean blood pressure (or a combination of both), combined with an absolute threshold (mmHg) or a threshold relative to a baseline (%). Diastolic blood pressure was never included in a definition. Other components of the definitions were the minimal duration of the episode that the blood pressure was below the threshold in order to be qualified as IOH (the minimal episode duration), the interval at which the blood pressure was measured (such as every 1, 3, or 5 min), and the measuring method (noninvasive or invasive). There were 6 articles that also included the requirement of a therapeutic action of the attending anesthesiologist, such as administering fluids or a vasopressor, in the definition of IOH.[1,2,15,16,21,22]

A wide variety of threshold pressure values to determine IOH was found, both absolute and relative to a baseline (table 1). The most frequently used definitions were a systolic blood pressure below 80 mmHg (n = 10), a decrease in systolic blood pressure more than 20% below baseline (n = 18), and the "combination definition" of an absolute and relative threshold described as a decrease in systolic blood pressure below 100 mmHg and/or 30% below baseline (n = 11). Definitions relative to a baseline require an unambiguous definition of this baseline. Of the 111 definitions that used a relative threshold, 55 (50%) actually presented the definition of this baseline. The baseline was most frequently based on blood pressure measurements taken immediately before induction of anesthesia. The minimal episode duration was less frequently mentioned than the baseline. In 14 of the 140 definitions (10%), a minimum duration was specified. For all other articles, it was not clear. If the minimal episode duration was mentioned, 1, 2, and 5 min were the most frequently used.

The measuring interval was not described in 29 of the 130 articles (22%). The most frequently used recording intervals for intraoperative blood pressures were 1 and 5 min (n = 36 and n = 38 articles, respectively). Both noninvasive and invasive measuring methods were described, depending on the clinical setting of the study. The method of measurement was not described in 37 articles (28%). The remaining articles used noninvasive methods (n = 63), invasive methods (n = 20), or both (n = 10).

In summary, 10 of the 140 found IOH definitions (7%) included descriptions of all of the aforementioned components (measurement method, blood pressure type, threshold value, baseline, minimal episode duration, and measurement interval).[19,22–30]

Part 2: Cohort Analysis

A reliable baseline blood pressure could be calculated for 15,509 (76%) of the 20,503 patients who underwent noncardiac surgery during general anesthesia in the selected time period. In the remaining patients, there was

Table 1. Thresholds of Intraoperative Hypotension as Found with the Literature Search

Definition	Articles (%)
Absolute systolic blood pressure thresholds	
SBP < 100 mmHg	2 (1.4)
SBP < 90 mmHg	5 (3.6)
SBP < 85 mmHg	1 (0.7)
SBP < 80 mmHg	10 (7.1)
Moderate: SBP < 100 mmHg, severe: SBP < 80 mmHg	2 (1.4)
Moderate: SBP < 85 mmHg, severe: SBP < 65 mmHg	1 (0.7)
SBP < 70 mmHg, later during surgery SBP < 100 mmHg	1 (0.7)
Relative systolic blood pressure thresholds	
Decrease in SBP > 10% from baseline	3 (2.1)
Decrease in SBP > 20% from baseline	18 (12.9)
Decrease in SBP > 25% from baseline	3 (2.1)
Decrease in SBP > 30% from baseline	7 (5.0)
Decrease in SBP > 40% from baseline	1 (0.7)
Decrease in SBP > 10 mmHg from baseline, moderate: < 90 mmHg	1 (0.7)
Decrease in SBP > 30 mmHg from baseline	1 (0.7)
Mild: decrease > 20%, moderate: 20–30%, severe: < 30% from baseline	1 (0.7)
Combinations of absolute and relative systolic blood pressure thresholds	
SBP < 100 mmHg or > 30% decrease from baseline	11 (7.9)
SBP < 100 mmHg or > 25% decrease from baseline	3 (2.1)
SBP < 100 mmHg or > 20% decrease from baseline	8 (5.7)
SBP < 100 mmHg and > 10% decrease from baseline	1 (0.7)
SBP < 95 mmHg or > 25% decrease from baseline	1 (0.7)
SBP < 90 mmHg or > 30% decrease from baseline	8 (5.7)
SBP < 90 mmHg or > 20% decrease from baseline	3 (2.1)
SBP < 80 mmHg or > 30% decrease from baseline	4 (2.9)
SBP < 80 mmHg or > 20% decrease from baseline	1 (0.7)
SBP < 75 mmHg or > 40% decrease from baseline	1 (0.7)
SBP < 100 mmHg, severe: decrease SBP > 30 mmHg from baseline	1 (0.7)
SBP < 90 mmHg or decrease > 30 mmHg from baseline	1 (0.7)
SBP < 90 mmHg or decrease > 20 mmHg from baseline	1 (0.7)
Absolute mean blood pressure thresholds	
MBP < 70 mmHg	1 (0.7)
MBP < 60 mmHg	2 (1.4)
MBP < 55 mmHg	2 (1.4)
MBP < 50 mmHg	1 (0.7)
Relative mean blood pressure thresholds	
Decrease in MBP > 10% from baseline, severe: 15% decrease	1 (0.7)
Decrease in MBP > 15% from baseline	1 (0.7)
Decrease in MBP > 20% from baseline	7 (5.0)
Decrease in MBP > 25% from baseline	5 (3.6)
Decrease in MBP > 30% from baseline	5 (3.6)
Combinations of absolute and relative mean blood pressure thresholds	
MBP < 60 mmHg or decrease > 30% from baseline	1 (0.7)
MBP < 65 mmHg or decrease > 30% from baseline	1 (0.7)
MBP < 70 mmHg and decrease > 40% from baseline or MBP < 60 mmHg	1 (0.7)
Combinations of systolic and mean blood pressure measurements	
SBP < 100 mmHg or decrease in MBP > 30% from baseline	1 (0.7)
SBP < 100 mmHg or decrease in SBP or MBP > 20% from baseline	1 (0.7)
SBP < 90 mmHg or decrease in MBP > 25% from baseline	2 (1.4)
SBP < 80 mmHg or MBP < 55 mmHg	1 (0.7)
No blood pressure measurement specification	
Decrease in BP > 30% from baseline	1 (0.7)
Decrease in BP > 25% from baseline	1 (0.7)
Decrease in BP > 20% from baseline	3 (2.1)
Decrease in BP > 20 mmHg from baseline	1 (0.7)

Total number of articles is greater than 130 because several articles contained more than one definition.

BP = blood pressure; MBP = mean blood pressure; SBP = systolic blood pressure.

no preoperative blood pressure measurement more than 3 min before the estimated time of induction of anesthesia. These patients were excluded from the analysis. Baseline characteristics of the cohort for which a baseline blood pressure could be calculated are presented in table 2. The incidence of IOH and the mean number of episodes of IOH according to the most frequently used definitions in the literature are presented in table 3. When using the definitions from the literature, the lowest incidence of IOH was found with a systolic blood

Table 2. Characteristics of the Cohort (n = 15,509)

Mean age (SD)	50.7 (17.2)
Male (%)	7,212 (46.5)
Mean duration of surgery in minutes (SD)	1:40 (1:33)
Median duration of surgery in minutes (25th, 75th percentiles)	1:12 (0:44,2:02)
Type of surgery (%)	
Elective surgery	12,644 (81.5)
Emergency surgery	2,865 (18.5)
General surgery	3,492 (22.5)
Plastic surgery	1,128 (7.3)
Gynecology/obstetrics	1,658 (10.7)
ENT and dental surgery	2,782 (17.9)
Neurosurgery	1,706 (11.0)
Eye surgery	1,677 (10.8)
Orthopedic surgery	1,244 (8.0)
Urology	756 (4.9)
Vascular surgery	1,066 (6.9)
Blood pressure measurement (%)	
Noninvasive	13,180 (85.0)
Invasive	2,329 (15.0)

ENT = ear, nose, and throat.

pressure below 70 mmHg for at least 5 min (5%), whereas the highest incidence was observed with a decrease in systolic blood pressure more than 10% from the baseline blood pressure without time criteria (99%).The curve showing the relation between blood pressure threshold and incidence of IOH using the information from table 3 showed a sigmoidal form. To construct the complete shape of the cumulative frequency distribution curve, threshold values higher and lower than the values found in the literature were also applied to the data set. This allowed us to calculate the incidence of IOH that would be found using these fictional thresholds (fig. 2).

Discussion

We conducted a systematic review to summarize the definitions of intraoperative hypotension that are used in the anesthesia literature, and found a large variation. These definitions were applied to intraoperative data from a large cohort of patients, resulting in an apparent occurrence of IOH varying between 5% and 99%. The relation between thresholds used in the definitions and the frequency of IOH is sigmoidal.

Some methodologic issues must be addressed. First, because we derived our data from daily clinical practice,

Table 3. Incidence of Intraoperative Hypotension in 15,509 Adult Noncardiac Surgery Patients

	Incidence of IOH, % (Mean Number of Episodes)		
	MED = 1 min	MED = 5 min	MED = 10 min
Absolute thresholds, mmHg			
Systolic			
< 100	81.5 (3.1)	71.6 (1.8)	56.4 (1.1)
< 95	74.5 (2.7)	62.4 (1.5)	45.1 (0.8)
< 90	64.3 (2.2)	49.3 (1.1)	30.9 (0.5)
< 85	53.2 (1.6)	35.0 (0.7)	17.4 (0.3)
< 80	41.2 (1.1)	20.1 (0.3)	7.4 (0.1)
< 75	30.7 (0.6)	10.5 (0.2)	3.1 (0.04)
< 70	21.2 (0.4)	4.6 (0.1)	1.3 (0.01)
< 65	14.0 (0.2)	2.4 (0.03)	0.7 (0.01)
Mean			
< 70	77.7 (3.0)	65.9 (1.7)	48.6 (1.0)
< 65	65.2 (2.4)	49.4 (1.2)	31.3 (0.6)
< 60	50.7 (1.6)	31.1 (0.7)	16.1 (0.3)
< 55	36.3 (0.9)	15.8 (0.3)	6.6 (0.1)
< 50	24.0 (0.5)	7.1 (0.1)	2.3 (0.03)
Relative thresholds, % from baseline			
Systolic			
> 10%	98.6 (2.7)	96.9 (2.0)	92.4 (1.5)
> 15%	96.9 (3.0)	93.7 (2.1)	86.9 (1.5)
> 20%	93.3 (3.2)	88.0 (2.1)	78.3 (1.5)
> 25%	86.7 (3.1)	78.6 (2.0)	66.5 (1.3)
> 30%	76.5 (2.8)	65.6 (1.7)	52.4 (1.0)
> 40%	52.2 (1.7)	37.1 (0.8)	24.0 (0.4)
Mean			
> 10%	98.5 (2.6)	96.7 (2.0)	91.7 (1.5)
> 15%	97.0 (2.9)	93.9 (2.1)	86.6 (1.5)
> 20%	94.1 (3.1)	89.0 (2.1)	79.4 (1.5)
> 25%	88.6 (3.1)	80.7 (2.0)	68.6 (1.3)
> 30%	80.1 (2.9)	68.9 (1.8)	54.9 (1.1)
> 40%	56.1 (1.9)	40.6 (1.0)	26.6 (0.5)

IOH = intraoperative hypotension; MED = minimal episode duration.

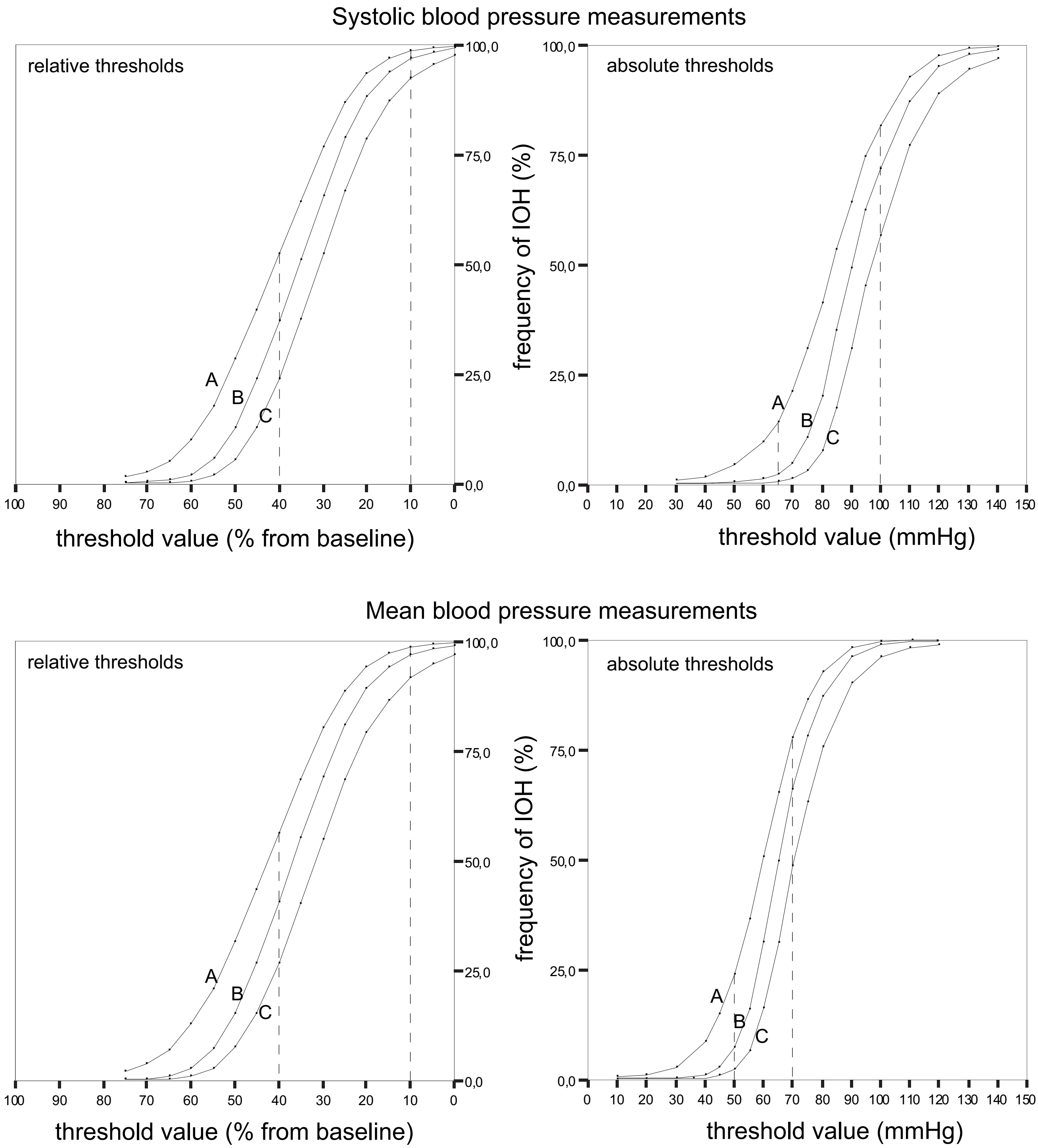

Fig. 2. Incidence of intraoperative hypotension (IOH) as a function of the chosen definition threshold. Each figure shows the relation between the various blood pressure thresholds and the incidence of intraoperative hypotension for both systolic (*upper two figures*) and mean blood pressures (*lower two figures*). The figures on the *left* show the blood pressure thresholds relative to a baseline (%), whereas the figures on the *right* show the absolute blood pressure thresholds (mmHg). In each figure, the sigmoidal curves shift to the right with increasing duration of the minimal episode length for IOH (A, B, and C). A = a minimal episode duration of 1 min below the designated threshold; B = a minimal episode duration of 5 min below the designated threshold; C = a minimal episode duration of 10 min below the designated threshold. The *vertical lines* represent the range of blood pressure thresholds as found in the literature.

there may have been some artifacts in the blood pressure data (*e.g.*, the surgeon leaning against the blood pressure cuff or movement artifacts). These artifacts may give both falsely low and falsely high blood pressures, resulting in an overestimation or underestimation of the incidence of IOH. However, because most artifactual readings are single readings, the eventual effects of artifactual measurements are minimized in the analyses where intraoperative hypotension was defined with a minimal duration of 5 or 10 min. Second, definitions using a threshold relative to a baseline blood pressure obviously require a value for this baseline. In the current study, we used the mean of all available blood pressure measurements before the time of induction of anesthesia. This definition of the baseline blood pressure is critically dependent on an exact recording of the time of induction of anesthesia. The induction time in our cohort data were manually entered by the anesthesiologist in the ARK system, generally after all activities around the induction and intubation have been completed. This may have resulted in errors. To minimize this error, the time of induction was defined as the time of administration of induction medication only if this event was before the first appearance of expired carbon dioxide registration. Otherwise, we assumed that the medication was given 3 min before carbon dioxide registration. These measures were taken to prevent that an initial decrease in blood pressure after induction was included in the calculation of the baseline blood pressure, which would have resulted in an inappropriately low baseline blood pressure and thus in an underestimation of the occurrence frequency of IOH. However, with this strict definition of induction, we found no blood pressure recordings before induction time in 24% of the cases, which restricted the cohort to 15,509 patients. This does not mean that in these cases there was no blood pressure measurement before induction of anesthesia, but that anesthesia was induced within the 3 min preceding first registration of expired carbon dioxide registration. Nevertheless, we excluded these cases rather than including a falsely low blood pressure baseline in 24% of the patients, resulting in falsely low incidences. Because this exclusion was random across the cohort, it is unlikely that it introduced bias. Still, this cohort is large enough to estimate the incidence of IOH as a function of relative blood pressure thresholds. It is unlikely that the aforementioned limitations have influenced the shape of the S-curve, although falsely low baseline blood pressures might cause a shift to the right. Finally, to reduce the amount of data presented in this article, we studied only the effects of varying the threshold values and minimal episode durations on the frequency of IOH. The other IOH criteria, such as blood pressure type, measurement method, or measurement interval, can be varied as well and are also likely to cause a similar left or right shift of the S-curve.

Many different definitions of IOH were found in the literature. These definitions were not only inconsistent in threshold values, but also in threshold type (absolute *vs.* relative), baseline (if required), blood pressure type (systolic *vs.* mean blood pressure), measurement method (noninvasive *vs.* invasive), measurement interval, and minimal episode duration. In our view, all of these components should be used in a proper definition of IOH. Nevertheless, only 10 (7%) of the 140 definitions analyzed contained descriptions of all of these criteria. The requirement of a therapeutic action by the attending anesthesiologist included in the definition of IOH raises a fundamental problem, because it implies that if a low blood pressure remains untreated, it would not qualify as IOH. Still, threshold value and type, baseline, blood pressure type, measurement method and interval, and minimal episode duration should be described unambiguously in a workable definition of IOH. For example, it is obviously not sensible to use a minimal episode duration for IOH of 1 min when the measuring interval is 5 min.[31]

In recent years, there has been renewed interest in the effect of IOH on short- and long-term outcomes.[3–7] Lienhart *et al.*[13] recently reported IOH to be one of the most important concerns associated with the occurrence of postoperative myocardial ischemia and infarction. However, many of the reported associations between IOH and adverse outcomes have been obtained using widely different, arbitrarily chosen blood pressure thresholds, in most cases without applying a restriction with respect to the duration of a hypotensive episode. For that reason, the results of the studies reporting such associations are difficult to compare, and associations between hypotension and outcome observed with one definition of IOH might not be observed when using even a slightly different definition. This is supported by our finding that small changes in threshold values may result in very different incidences of IOH, especially in the commonly used definitions covering the steep area of the cumulative frequency distribution curve (fig. 2). Moreover, it is remarkable to find definitions of IOH that include combinations of absolute and relative thresholds from different areas of the cumulative frequency distribution curve.[31,32] Still, basic physiology teaches that if blood pressure becomes "low enough for a period that is long enough," organ perfusion will be compromised, which in turn might have detrimental effects to end organs. However, what is "too low" and what is "too long"? A clinically more relevant question would be at what threshold and episode duration the IOH will affect clinically relevant patient outcomes. These different patient outcomes (*e.g.*, myocardial ischemia, ischemic stroke, "watershed" infarction) will probably have different threshold levels, both for the minimum blood pressure threshold value and for the minimal episode duration, at which significant associations can be found. Furthermore, these thresholds are also likely to depend on patient characteristics, such as age and comorbidity. There is some evidence for this assertion from studies on critical spinal cord perfusion. For example, de Haan *et al.*[33] reported a decreased ischemic tolerance of the spinal cord to a lowering of perfusion pressure after clamping of noncritical segmental arteries in pigs. Similarly, one can hypothesize that a patient with peripheral vascular disease undergoing surgery will have a different tolerance for low blood pressures as compared with a healthy patient undergoing the same procedure. One can also imagine that a patient undergoing surgery with significant blood loss has a different tolerance for low blood pressures as compared with the same patient undergoing minor surgery. IOH thus becomes a dynamic phenomenon depending on patient characteristics and surgical factors rather than a static phenomenon based on fixed, arbitrarily chosen thresholds.

There is no accepted single definition for IOH. When published IOH criteria from the recent anesthesia literature are applied to actual patient data, the incidence of IOH varies between 5% and 99%. It is likely that this variation in IOH incidence has implications for the reported association between IOH and adverse perioperative outcomes, because associations observed with one definition might not be found using even a slightly different definition. We suggest that the problem of IOH should be approached as a dynamic phenomenon depending on various factors, rather than dichotomizing blood pressures based on arbitrarily chosen thresholds.

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