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Variation in perioperative cerebral and hemodynamic monitoring during carotid endarterectomy

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Background: Hemodynamic disturbances cause half of the perioperative strokes following carotid endarterectomy (CEA). Guidelines strongly recommend strict pre- and postoperative blood pressure (BP) monitoring in CEA patients, but do not provide firm practical recommendations. Although in the Netherlands 50 centres perform CEA, no national protocol on perioperative hemodynamic, and cerebral monitoring exists. To assess current monitoring policies of all Dutch CEA-centres, a national survey was conducted.

Methods: Between May and July 2017 all 50 Dutch CEA-centres were invited to complete a 42-question survey addressing perioperative hemodynamic and cerebral monitoring during CEA. Nonresponders received a reminder after 1 and 2 months. By November 2017 the survey was completed by all centres.

Results: Preoperative baseline BP was based on a single bilateral BP-measurement at the outpatient-clinic in the majority of centres ($n = 28$). In 43 centres (86%) *pre*-operative monitoring (transcranial Doppler (TCD, $n = 6$), electroencephalography (EEG, $n = 11$), or TCD + EEG ($n = 26$)) was performed as a baseline reference. Intraoperatively, large diversity for type of anaesthesia (general: 45 vs. local [LA]:5) and target systolic BP (>100 mm hg – 160 mm hg [$n = 12$], based on preoperative outpatient-clinic or admission BP [$n = 18$], other [$n = 20$]) was reported. Intraoperative cerebral monitoring included EEG + TCD ($n = 28$), EEG alone ($n = 13$), clinical neurological examination with LA ($n = 5$), near-infrared spectroscopy with stump pressure ($n = 1$), and none due to standard shunting ($n = 3$). Postoperatively, significant variation was reported in standard duration of admission at a recovery or high-care unit (range 3–48 hr, mean:12 hr), maximum accepted systolic BP (range >100 mm hg – 180 mm Hg [$n = 32$]), postoperative cerebral monitoring (standard TCD [$n = 16$], TCD on indication [$n = 5$] or none [$n = 24$]) and in timing of postoperative cerebral monitoring (range directly postoperative – 24 hr postoperative; median 3 hr).

Conclusions: In Dutch centres performing CEA the perioperative hemodynamic and cerebral monitoring policies are widely diverse. Diverse policies may theoretically lead to over- or under treatment. The results of this national audit may serve as the baseline dataset for development of a standardized and detailed (inter)national protocol on perioperative hemodynamic and cerebral monitoring during CEA.

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INTRODUCTION

Strict perioperative arterial blood pressure (BP) control is advocated to preserve adequate cerebral perfusion during carotid endarterectomy (CEA).[1] Despite these efforts, under the currently applied protocols, hemodynamic disturbances during CEA may contribute to intraprocedural strokes, and play an important role in the aetiology of postoperative strokes.[1–4] Additionally, an increased risk of perioperative cerebral events has been reported in patients with elevated preoperative BP.[5,6] Intraoperative hypoperfusion is the most frequent cause of cerebral ischemia whereas postoperative ipsilateral hyperperfusion has been correlated to cerebral hyperperfusion syndrome (CHS) resulting in cerebral haemorrhage when left untreated.[4,7,8] Theoretically, periprocedural strokes due to hemodynamic disturbances seem preventable. These observations clearly lead to better understanding on optimal perioperative hemodynamic and cerebral monitoring policy to adequately identify and timely address these disturbances.

Cerebral monitoring techniques such as electroencephalography (EEG), transcranial Doppler (TCD), or Near Infra-Red Spectroscopy (NIRS) all claim to detect disturbances in cerebral blood flow in order to prevent cerebral ischemia and to assess the need for shunt placement during carotid cross-clamping under general anesthesia.[9–11] Besides, intraoperative changes in the middle cerebral artery blood flow velocity (MCA*V*) detected by TCD however remains the gold standard for CHS risk prediction following CEA.[12,13] Postoperative TCD measurements 2 hr and 24 hr in addition to intraoperative TCD measurements have been shown to increase the prediction rate for CHS.[12,14]

Recent guidelines by the European Society for Vascular Surgery (ESVS) recommend preoperative antihypertensive treatment in patients with hypertension to maintain long-term BP <140/90 mm Hg. Furthermore, when preoperative systolic BP exceeds 180 mm Hg, it is advised to first treat hypertension before proceeding with CEA. Postoperatively, invasive BP monitoring is recommended during the first 3–6 hr at a recovery or high-care unit, followed by hourly noninvasive BP control during the first 24 hr. Unfortunately, specific recommendations regarding the intraoperative, and postoperative BP thresholds, BP treatment or on the type or duration of cerebral monitoring are still lacking.[1,15]

In the Netherlands, CEA is currently performed in 50 medical centres (total of 2306 CEA-procedures in 2016, range 20–91 CEA-procedures per centre).[16] Nevertheless, a national protocol on optimal perioperative hemodynamic, and cerebral monitoring does not exist. To assess the currently applied monitoring policies, we conducted a national survey on perioperative hemodynamic and cerebral monitoring during CEA within the Netherlands.

METHODS

Survey

Between May 2017 and July 2017 vascular surgeons of all Dutch medical centres performing CEA were invited by email to participate in an online survey (SurveyMonkey Analyze 2017, see Supplement 1.). Nonresponders received a maximum of 2 reminder invitations, *sent* 1, and 2 months after initial invitation. The survey contained 42 questions addressing type of anaesthesia, preoperative, intraoperative and postoperative hemodynamic policies and monitoring, cerebral monitoring and length of stay on a high care unit (HCU). The survey had been compiled, discussed and improved on by an expert panel consisting of vascular surgeons and a vascular medicine specialist. Questions were multiple-choice with the option to clarify the answer in a text field. In case of multiple vascular surgeons performing CEA within 1 centre, a consensus was obtained by the corresponding vascular surgeon on behalf of his/her colleagues to represent their centres' policy. Results presented by this study reflect the performances per centre, not of a single surgeon. The database of the Dutch Audit for Carotid Interventions (DACI) was used to calculate numbers of CEA procedures per centre in 2016.[16]

Definitions

CEA was performed under general or local anaesthesia, via eversion or longitudinal incision with patch or primary closure. Cerebral monitoring included EEG, TCD, NIRS, stump pressure or intraoperative neurological examination in case of local anaesthesia. Perioperative period can be divided in preoperative phase, intraoperative phase, and postoperative phase. Preoperative phase is the in-hospital period from admission on the ward to surgery. Intraoperative phase extends from moment of admission to the operating room (OR) until patient is transported to the

recovery unit. Postoperative phase is defined from admission to recovery unit until hospital discharge. Based on volume, medical centres were subdivided into low volume centres (LVC): 20–50 CEA procedures annually, and high-volume centres (HVC): >50 CEA procedures annually.[16] High care unit was defined as a nursing ward with availability of continuous invasive monitoring and observation, and intravenous BP support (i.e. medium care unit, intensive care unit). Recovery unit was determined as a post-anaesthetic care unit for short-term observation directly after surgery. 'The general protocol for BP-regulation' the questions in the survey are referring to, is defined as a multidisciplinary team approach for carotid endarterectomy in the entire health care chain, not specified per perioperative period.

Statistical analysis

Data were collected with an online survey tool, SurveyMonkey Analyze. The results were processed, and analysed using IBM SPSS Statistics for Microsoft Windows version 25.0th Edition (IBM Corp., Armonk, NY, USA). Categorical data were reported as a quantity with percentages. Continuous data were reported as means with standard deviation (SD) when normally distributed and median with interquartile range (IQR) when nonnormally distributed. Outcomes were reported separately presented for perioperative phase. In addition, per perioperative phase results were stratified for centre volume.

Ethical approval of research committee was not necessarily due to the aspect of this study; survey among vascular surgeons without the use of any patient data.

RESULTS

Participants

In total, all 50 Dutch centres performing CEA completed the survey (100% response rate) in November 2017, provided by either individual surgeons ($n = 45$) or by consensus ($n = 5$). The survey was completed by surgeons from all CEA-centres. In 2016, 32 LVC (64%; total: 1119 CEAs, mean: 35/centre [range 20–49]) and 18 HVC (36%; total: 1187, mean: 66/centre [range 51–91]) were identified.[17] CEA was performed under general anaesthesia (GA) in 45 centres (90%), solely under local anaesthesia (LA) in 1 centre (2%) whereas in 3 centres (6%) the decision for GA versus LA was patient specific.

Blood pressure protocol

In 39 of 50 CEA-centres (78%; LVC 24 and HVC 15) a general protocol for BP regulation during CEA was available and in use. A specific protocol for CHS was available in 34 centres (68%; LVC 21 and HVC 13). Protocols concerning BP regulation specifically differentiating between the preoperative, intraoperative, and postoperative phases were available in a fewer centre. Just 15 centres (30%; LVC 8 and HVC 7) reported a specific protocol concerning preoperative BP regulation, 26 centres (52%; LVC 17 and HVC 9) for intraoperative BP regulation and 40 centres (80%; LVC 25 and HVC 15) reported an active protocol specific for postoperative BP regulation.

Antihypertensive treatment

No consensus existed regarding perioperative antihypertensive drug therapy. Preoperatively, in-hospital hypertension was not a contraindication for surgery in almost half of centres ($n = 23$). If preoperative antihypertensive treatment was required on the ward, oral labetalol or beta-blockers were administered most commonly. Intraoperatively and postoperatively, intravenous labetalol was administered most frequently (Table I). Many different specialists were responsible for BP treatment during the periprocedural phases (Table I).

Periprocedural hemodynamics

In the majority of centres (66%; LVC 21, HVC 12), the preoperative BP-measurement was based on a single noninvasive bilateral BP-measurement at the outpatient clinic, in which the highest value was considered as the most accurate. In seventeen centres (34%; LVC 11, HVC 6) the preoperative BP was performed by a random side single BP-measurement or a standardized side single BP-measurement. Intra- and postoperatively, centres predominantly performed invasive monitoring (intraoperatively 48 centres; LVC 31, HVC 17, and postoperatively 46 centres; LVC 30, HVC 16).

There was not much similarity between centres on the level of maximum-accepted BP thresholds periprocedural, either systolic or diastolic. A broad and very heterogeneous range of applied systolic BP thresholds during the different phases were reported by all centres (Table II). Postoperative maximum-accepted systolic BP thresholds on the ward as well as for discharge also varied extensively, ranging from <140 mm Hg to <180 mm Hg or the preoperative admission BP.

Table I. Hemodynamic topics

	Preoperative			Intraoperative			Postoperative		
	LVC (n = 32)	*HVC (n = 18)*	*Total (n = 50)*	*LVC (n = 32)*	*HVC (n = 18)*	*Total (n = 50)*	*LVC (n = 32)*	*HVC (n = 18)*	*Total (n = 50)*
Responsible for target BP									
Vascular surgeon	-	-	-	11 (34)	10 (56)	21 (42)	16 (50)	14 (78)	30 (60)
Anaesthesiologist	1 (3)	1 (6)	2 (4)	4 (13)	-	4 (8)	-	-	-
Vascular surgeon & anaesthesiologist	-	-	-	11 (34)	6 (33)	17 (34)	5 (16)	2 (12)	7 (14)
Internal medicine specialist	13 (41)	7 (39)	20 (40)	-	-	-	-	-	-
Vascular medicine specialist	7 (22)	5 (28)	12 (24)	-	-	-	-	-	-
Internal + vascular medicine specialist	5 (16)	3 (17)	8 (16)						
Intensive care specialist	-	-	-	-	-	-	3 (9)	1 (6)	4 (8)
Vascular surgeon + neurologist	-	-	-	1 (3)	1 (6)	2 (4)	-	-	-
Combination of specialists (all the above)	5 (16)[a]	1 (6)[a]	6 (12)[a]	3 (9)[b]	1 (6)[b]	4 (8)[b]	8 (25)[c]	1 (6)[c]	9 (18)[c]
Non applicable	1 (3)	1 (6)	2 (4)	2 (6)	-	2 (4)	-	-	-
Antihypertensive agents, if required									
RAAS inhibitors	-	1 (6)	1 (2)	-	-	-	-	-	-
ACE inhibitors	1 (3)	1 (6)	2 (4)	1 (3)	-	1 (6)	-	-	-
Other beta-blockers	6 (19)	-	6 (12)	5 (16)	2 (11)	7 (14)			
Labetalol, intravenously	-	-	-	16(50)	5 (28)	21 (42)	23 (72)	12 (67)	35 (70)
Labetalol, oral	7 (22)	2 (11)	9 (18)	-	-	-	2 (6)	1 (6)	3 (6)
Clonidine, intravenously	-	-	-	-	-	-	1 (3)	-	1(2)
Nicardipine, intravenously	-	-	-	-	-	-	2 (6)	1 (5)	3 (6)
Other	5 (16)	4 (22)	9 (18)	5 (16)	4 (22)	9 (18)	4 (13)	4 (22)	8 (16)
Unknown by respondent	13 (41)	10 (56)	23 (46)	10 (31)	8 (44)	18 (36)	-	-	-

Data are expressed as quantities with (percentages). LVC represent low volume centres that perform 20-50 CEA procedures annually. HVC represent high volume centres that perform >50 CEA procedures annually. BP: blood pressure.
[a]Combination of specialist preoperatively consisting of internal medicine specialist, neurologist, cardiologist, anaesthesiologist, vascular surgeon, vascular medicine specialist.
[b]Combination of specialists consisting of anaesthesiologist, vascular surgeon, and neurologist.
[c]Combination of specialists postoperatively consisting of vascular surgeon, anaesthesiologist, and intensive care specialist.

The basis upon the systolic BP thresholds is defined were highly diverse, varying from protocol-based, experienced-based, based on preoperative BP-measurement, and cerebral monitoring-based to a combination of the previously mentioned (Table II). BP thresholds for discharge were primarily based upon the level of preoperative BP (11 centres) or local protocol (20 centres).

Due to the diversity and small numbers no differences or trends between low volume centres and high-volume centres were observed for the systolic blood pressure thresholds or the basis upon these systolic blood pressure thresholds.

Follow up of blood pressure

In 42 of the 50 centres (84%; LVC 29 and HVC 13), the recommended maximum accepted systolic BP for discharge was documented in the electronic patient file, in the letter of discharge to patient's general practitioner (GP) or both. Follow up on BP and BP threshold was performed in most centres by

Table II. Hemodynamic thresholds

	Preoperative *Total (n = 50)*	Intraoperative *Total (n = 50)*	Postoperative *Total (n = 50)*
Maximum systolic BP threshold			
No	26 (52)	7 (14)	0 (0)
Yes	24 (48)	43 (86)	50 (100)
	8 (16)	-	1 (2)
- 180 mm hg			
	1 (2)	-	2 (4)
- 170 mm hg			
	6 (12)	2 (4)	12 (24)
- 160 mm hg			
	3 (6)	4 (8)	11 (22)
- 150 mm hg			
	1 (2)	4 (8)	4 (8)
- 140 mm hg			
	1 (2)	-	-
- 130 mm hg			
	0	1 (2)	1 (2)
- 120 mm hg			
	0	1 (2)	1 (2)
- >100 mm hg			
	3 (6)	18 (36)	8 (16)
- BP at admission/outpatient clinic			
	1 (2)	1 (2)	-
- BP at admission + 10 mm Hg			
	-	5 (10)	-
- BP at admission + 20 mm Hg			
	-	1 (2)	-
- 20% below preoperative BP			
	-	2 (4)	1 (2)
- Preoperative MAP ±10			
	-	1 (2)	-
- Preoperative MAP 80-90			
	-	-	2 (4)
- <180, unless TCD >100%			

(*continued on next page*)

Table II (*continued*)

	Preoperative *Total (n = 50)*	Intraoperative *Total (n = 50)*	Postoperative *Total (n = 50)*
- <160 mm Hg, unless TCD >100% or high risk	-	-	3 (6)
- Dependent on TCD measure	-	-	2 (4)
- Normotensive BP	-	2 (4)	2 (4)
- missing	-	1 (2)	-
Threshold based upon:			
- Protocol		6 (12)	17 (34)
- Experienced-based		9 (18)	3 (6)
- Preoperative BP		30 (60)	7 (14)
- Experience + preoperative BP		2 (4)	3 (6)
- Experience + preoperative/intraoperative BP		1 (2)	1 (2)
- Experience + preoperative BP + postoperative BP		-	1 (2)
- Experience + protocol + preoperative BP		-	1 (2)
- Experience + protocol + intraoperative BP		-	1 (2)
- TCD pre/intra/post or combination		-	7 (14)
- TCD intraoperative & preoperative BP		-	1 (2)
- TCD postoperative & postoperative BP		-	1 (2)

(*continued on next page*)

Table II (*continued*)

	Preoperative *Total (n = 50)*	Intraoperative *Total (n = 50)*	Postoperative *Total (n = 50)*
		-	1 (2)
- TCD postoperative & protocol			
		-	1 (2)
- Protocol + preoperative BP + intraoperative BP			
		-	1 (2)
- Protocol + intraoperative BP			
- One-fits-all-policy			
		-	1 (2)
• 160–180 mm hg			
		-	1 (2)
• <160 mm hg			
		-	3 (6)
• <150 mm hg			

Data are as quantity with percentages. TCD, transcranial Doppler; BP, blood pressure; MAP, mean arterial pressure.

the GP (24 centres, 48%) or vascular surgeon (12 centres, 24%). A small number of centres referred this follow-up to the internal or vascular medicine specialist (4 vs. 6 centres, respectively).

Cerebral monitoring

In the preoperative phase, cerebral monitoring was performed in 43 CEA-centres (86%) for application baseline purposes. Intraoperatively, for CEA under GA, more than half the centres used EEG combined with TCD (62%), 13 centres (29%) solely applied EEG-monitoring while 1 centre used NIRS combined with stump pressure (2%). In 3 centres no intraoperative cerebral monitoring was performed due to routine shunting of the internal carotid artery. The centres that performed CEA under LA monitored their patients by continuous awake cerebral neurological examination (CNE). Postoperatively, approximately half of the centres did not perform cerebral monitoring (48%) or only on indication (TCD: 10%, EEG: 2%). In only 16 centres (32%), EEG and/or TCD monitoring were part of the standard postoperative care. The timing of this standardized postoperative monitoring varied from directly after surgery up to 24 hr after surgery (median: 3 hr) (Table III, Fig. 1).

Postoperative observation

Immediately after surgery, patients were admitted to the recovery unit in 16 centres (32%; LVC 11 and HVC 5). In the majority of centres, patients were admitted to a HCU like intensive care or medium care unit as a standard procedure (60%; LVC 19 and HVC 11). The standard observation duration ranged from 3 to 48 hr (mean: standard 12 hr). Centres based the duration of observation on a protocol (68%; LVC 20, and HVC 14) or on patient-specific parameters (32%, LVC 12, and HVC 4) (Table IV, Fig. 2).

DISCUSSION

Perioperative hemodynamic and cerebral monitoring policies during carotid surgery vary widely. Although the majority of centres do have a written (general) protocol on BP regulation and more specifically on prevention of CHS after CEA, a highly heterogeneous approach in all phases of

Table III. Cerebral monitoring

Cerebral monitoring	Preoperative			Intraoperative			Postoperative		
	LVC ($n = 32$)	HVC ($n = 18$)	Total ($n = 50$)	LVC ($n = 32$)	HVC ($n = 18$)	Total ($n = 50$)	LVCm ($n = 32$)	HVC ($n = 18$)	Total ($n = 50$)
TCD&EEG	15 (47)	11 (61)	26 (52)	15 (47)	13 (72)	28 (56)	4 (13)	0	4 (8)
TCD	4 (13)	2 (11)	6 (12)	-	-	-	6 (19)	6 (33)	12 (24)
EEG	8 (25)	3 (17)	11 (22)	10 (31)	3 (17)	13 (26)	1 (3)	0	1 (2)
CNE	-	-	-	4 (13)	1 (6)	5 (10)	3 (9)	0	3 (6)
NIRS + stump pressure	-	-	-	1 (3)	0	1 (2)	-	-	-
TCD on indication	-	-	-	-	-	-	2 (6)	3 (17)	5 (10)
EEG on indication	-	-	-	-	-	-	0	1 (6)	1 (2)
None	5 (16)	2 (11)	7 (14)	2 (6)	1 (6)	3 (6)	16 (50)	8 (44)	24 (48)

Data are expressed as quantities with (percentages). LVC represent low volume centres that perform 20-50 CEA procedures annually. HVC represent high volume centres that perform >50 CEA procedures annually. TCD, transcranial Doppler; EEG, electroencephalography; NIRS, near-infrared spectroscopy; CNE, cerebral neurological examination.

Table IV. Postoperative admission high care unit

	Postoperative		
	LVC (n = 32)	*HVC (n = 18)*	*Total (n = 50)*
Standard admission HC unit			
- IC unit (%)	10 (31)	6 (33)	16 (32)
- MC unit (%)	9 (28)	5 (28)	14 (28)
- Observatory unit (%)	11 (34)	5 (28)	16 (32)
- Other (%)	2 (6)	2 (11)	4 (8)
Duration of observation based on:			
- Protocol, observatory unit (%)	6 (19)	1 (6)	7 (14)
- Protocol, MC unit (%)	6 (19)	4 (13)	10 (20)
- Protocol, IC unit (%)	5 (16)	3 (6)	8 (16)
- Protocol, observatory + HC unit (%)	3 (9)	6 (19)	9 (18)
- Patient specific, MC unit (%)	5 (16)	1 (6)	6 (12)
- Patient specific, IC unit (%)	4 (22)	3 (17)	7 (14)
- Patient specific, depending on patient's recovery (%)	3 (17)	0	3 (6)

Data are expressed as quantities with (percentages). LVC represent low volume centres that perform 20–50 CEA procedures annually. HVC represent high volume centres that perform >50 CEA procedures annually. IC, intensive care; MC, medium care; HC, high care. Data are as quantity with percentages.

the in-hospital period was reported. Intraoperative and postoperative cerebral monitoring policies and applied baseline BP-measurements differed substantially. The wide variety in centre-specific policies results in fragmented care, and as a consequence seriously limits the comparability of outcome between centres.

The recent 2017 guideline on treatment of atherosclerotic carotid artery disease published by the ESVS provides several recommendations regarding periprocedural hypertension treatment and cerebral monitoring.[1] However, no specific guidance was provided regarding the determination of baseline BP, the maximum accepted periprocedural BP, nor use of cerebral monitoring to minimize the risk of complications. Level 1 evidence regarding these topics is lacking, most likely due to the difficulty to prove that these monitoring factors directly affect clinical outcome.[1] Still, since 1 out of 3 perioperative events in carotid surgery is attributed to hemodynamic origin and such events seem preventable, improvement in perioperative care with standardization of best practice is likely to be indicated and some form of monitoring mandatory.[4]

Although not specified by the guidelines, intraoperative arterial BP during CEA is advised to be kept between baseline, and 20% above

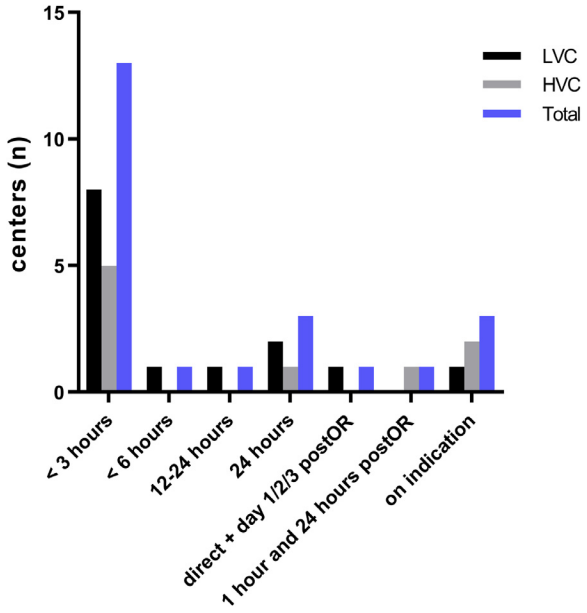

Fig. 1. Timing of cerebral monitoring postoperative. Footnotes: LVC represent low volume centres that perform 20–50 CEA procedures annually. HVC represent high volume centres that perform >50 CEA procedures annually. postOR, post -surgery.

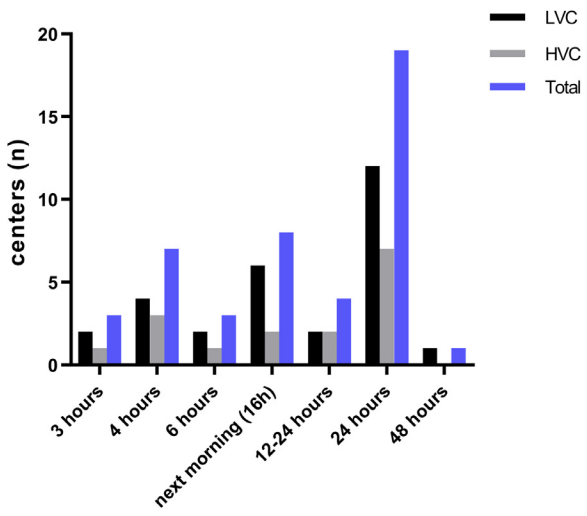

Fig. 2. Duration of postoperative admission at observational ward. Footnotes: LVC represent low volume centres that perform 20-50 CEA procedures annually. HVC represent high volume centres that perform >50 CEA procedures annually.

to minimize the risk for intraoperative stroke.[18] Unfortunately, the applied term 'baseline' is poorly defined in the literature. Frequently, this led to the use of a baseline BP based on BP-measurement in the OR before induction of anaesthetics, which is often higher (up to 14 mm hg) compared to BP measured at the outpatient-clinic for preoperative evaluation.[19–21] Additionally, it can be challenging to achieve and maintain these BP targets intraoperatively, and the direct effects of altering or shifting these strict intraoperative BP thresholds have not yet been investigated for efficacy in preventing CHS. For postoperative BP management, a 1 size fits all systolic BP policy by treating >170 mm hg in patients without symptoms or >160 mm hg in patients with symptoms is often suggested to prevent postoperative complications.[22] However, this policy may cause significant overtreatment and extensive workload, but will not prevent CHS since this complication may still occur without systolic hypertension (i.e. systolic BP ≤140 mm hg).[14,23,24] As a consequence, a standard 160 mm Hg maximum BP policy will still allow for severe complications of CHS to occur despite following a BP policy.

Intraoperatively, the majority of centres have implemented both EEG and TCD monitoring as standard clinical care. These cerebral monitoring methods inform the surgeon on the presence of both macro- and micro-emboli during carotid mobilization and dissection phase, guide to selectively shunt the carotid artery and ensures continuous shunt function, which is also relevant in standard shunting.[3,9–11] On international level, no strict recommendations are provided by ESVS guideline concerning targeted monitoring, and quality control.[1]

The ESVS guideline recommends to invasively monitor BP of CEA patients on an advanced care unit during the first 3–6 hr postoperatively. We observed that 60% of the centres admitted their CEA patients to a HCU for an average duration of 22 hr as part of standard postoperative care. Besides overtreatment, it seems evident that standard postoperative admission to a HCU goes hand in hand with high costs and workload.[1] Interestingly, no studies provide any insight regarding the specific interventions which are adopted during the first twenty-four hr admission to a HCU in comparison to admission to the ward/recovery unit. This makes it hard to objectify the clinical benefit of standard HCU admission. By implementing TCD monitoring to perioperative clinical care, patients at high risk of CHS can be easily identified. As a consequence, only a small subset of patients requires strict and immediate BP lowering and monitoring on a HCU while the majority of operated patients can safely be discharged for further BP regulation via the nursing ward or via the outpatient clinic.[14,25] This risk based strategy will lead to a decrease in hospital costs and is more patient-friendly than standard

extended strict BP monitoring by a radial artery line.

On the other hand, the need for fifty different centres performing CEA in the Netherlands containing 18 HVC and 32 LVC with a mean caseload of 46 CEAs per centre per year can be questioned. Hospital care and specific specialized treatments are increasingly centralized, resulting in high operator and centre volume which have been associated with a decreased risk of procedural death and stroke after CEA and CAS.[26] We predict that centralization with standardized protocols for perioperative care among the country may lead to lower periprocedural complication rates.

In the end, the overall aim is to achieve best clinical care. Therefore, since 2013 it is mandatory for all Dutch centres performing carotid artery interventions to provide data that include patient characteristics and surgical treatment annually to DACI. The objective of this nationwide audit is to measure and improve the quality of care in carotid interventions and to monitor the adherence of national guidelines and clinical outcomes (i.e. neurological outcomes like TIA/stroke, postoperative bleeding, death).[16] The wide variability of the centre-specific perioperative hemodynamic and cerebral monitoring policies has not been included in this audit and may be the cause of a distorted view of national clinical outcomes and limits the comparability. This emphasizes the need for a univocal perioperative protocol or at least include these variables in the audit.

In Dutch centres performing CEA the perioperative hemodynamic and cerebral monitoring policies are widely diverse. The wide variety in centre-specific policies results in fragmented care. Although we did not directly relate these different policies to outcome of care, one may assume that very strict protocols with tight BP thresholds may lead to overtreatment while less strict protocols may consequently cause undertreatment of patients. The use of a consensus national protocol using well defined threshold therefore may theoretically lead to improved care in the benefit of the patient, preventing both under- and over-treatment.

The results of this national survey should be interpreted in light of several limitations. First, the survey used in this study was a nonvalidated questionnaire. Due to the lack of availability of validated questionnaires on this topic, the survey was compiled by an expert panel consisting of vascular surgeons, and a vascular medicine specialist. However, as most required data focused on objective measures and not subjective interpretation, we believe that our data provide a good insight in current Dutch practice. Second, in 5 out of fifty centres a post-hoc consensus was mandatory due to a contradiction in answers of multiple vascular surgeons within 1 centre. In case 1 surgeon per centre filled out the survey, this answer was accepted although it is likely that the same variety existed within that centre. This makes the validity of the responses by a single surgeon slightly disputable as different approaches may be applied by individual surgeons. Finally, no association was made between the used hemodynamic targets and cerebral monitoring policies and periprocedural stroke/death rate per centre. Therefore, the presented results should be interpreted as a general overview, and not as individual centre results.

In conclusion, applied perioperative hemodynamic, and cerebral monitoring policies during carotid surgery among Dutch centres are widely diverse. In only 1 in every 2 centres a specific protocol concerning intraoperative BP regulation was available. As hemodynamic disturbances are an important cause of potentially preventable periprocedural strokes, we consider that improvements in perioperative monitoring are required. Alignment of centre-specific policies to 1 detailed univocal (inter)national protocol on perioperative hemodynamic and cerebral monitoring during CEA would improve standardization of care and facilitate outcome comparisons.

AUTHORS' CONTRIBUTION

LF,RT,BP,JW,EH,LK,WK,GB: study design. LF,GB: data collection. LF,GB: data analysis and interpretation. LF,GB: statistical analysis. LF,GB: writing and figures. LF,RT,BP,JW,EH,LK,WK,GB: revisions, and final approval.

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DECLARATION OF INTEREST

The authors declare that they have no conflict of interest.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.avsg.2021.06.015.

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