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Current Application of NIRS and CPB Initiation Times in German Cardiac Surgery Centers: A Survey

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Abstract: Near-infrared spectroscopy (NIRS) has been widely used in cardiac surgery to monitor cerebral oxygen supply. The initiation and perioperative management of cardiopulmonary bypass (CPB) constitute critical events in modifying the normal physiology of adequate blood and oxygen supply to the brain. First, little is known about how frequent NIRS is really used. Second, there are varying practices on how to initiate CPB. We therefore conducted a survey in Germany to get an idea of NIRS usage in cardiac surgery for the duration of initiation of CPB protocols. A web-based e-mail survey using commercial SurveyMonkey® (SurveyMonkey, San Mateo, CA) software was conducted in August 2017 including all German cardiac surgery centers. About 75% of the perfusion departments do not use NIRS as a standard monitoring device. It is usually reserved for clinical scenarios where cerebral perfusion might be impaired such as aortic arch surgery or carotid artery stenosis. Only one-third of the departments use a standardized duration of initiation of CPB despite a common belief of potential harm with fast initiation. The usual applied time to initiate CPB ranges from 30 to 120 seconds. Our survey revealed that the NIRS technology is only used in specific types of cardiac surgery to this date. In addition, there is a clear need for scientific studies on how to initiate CPB in the best way for the patient. **Keywords:** NIRS, CPB, initiation time, cerebral blood flow, oximetry. *J Extra Corpor Technol. 2021;53:177–80*

One of the keys to patient safety and quality of care in cardiac surgery is the prevention of neurological disability. Besides cerebral microemboli and an induced inflammatory response (1,2), episodes of cerebral hypoperfusion and hemodilution (3–5) appear to be central in the pathogenesis of postoperative cognitive dysfunction (POCD) after cardiopulmonary bypass (CPB). Therefore, detecting changes in cerebral oxygen delivery during CPB is crucial to apply strategies to avoid inadequate oxygen supply to the brain. Near-infrared spectroscopy (NIRS) is a technology currently being used in cardiothoracic surgeries for detecting cerebral ischemic events by measuring regional cerebral oxygen saturation ($rScO_2$) (6,7). Still, despite being available to clinicians over 20 years, a knowledge gap remains in terms of correct interpretation, subsequent clinical decisions, and general usefulness of NIRS measurements. Furthermore, it is unclear if periods of varying pump flow rates (e.g., initiation and aortic cross clamping) play a critical role in the overall impact of the CPB on neurological integrity, as there is no scientific literature available looking at the clinical outcomes of different CPB protocols. Our survey aims to gain a better impression on the reasoning and frequency of NIRS application in the cardiac operating theater as well as understanding variation in duration of initiation of CPB.

METHODS

Before designing the survey, a thorough literature review was performed using Pubmed® and Google Scholar online search engines. Search phrases were entered as follows: CPB and initiation, CPB and cerebral oximetry, CPB and cerebral blood flow, heart lung machine and initiation, heart lung machine and cerebral oximetry, or heart lung machine and cerebral blood

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flow. Secondary sub-words were start, fast, slow, NIRS, pump, and comparison and were added to the initial phrases after the primary search. The web-based e-mail survey was conducted in August 2017 with a 6-week allowance of completion starting with the sent date. For simplicity, five questions were chosen to get a picture of the daily practice of NIRS and CPB initiation times in cardiac surgery. Questions 1, 3, and 5 could be answered with either yes or no. Questions 2 and 4 had given answer choices to be checked by the participants. The questionnaire contained the following questions (Table 1).

The questionnaire was digitalized using commercial SurveyMonkey® software and sent via e-mail for singular online processing to the chief perfusionist of each center. For control purposes, each cardiac surgery center was given a number of 1–78 and each questionnaire was confidential and anonymous without being traceable back to the participating center. The center was able to answer all or skip questions, as well as multiple answers were allowed for Questions 2 and 4. Received data were exported to a Microsoft-Access® file (Microsoft Corporation, Redmond, WA) and checked for entry errors before being analyzed with Prism 3.0 Software (GraphPad Software Inc., La Jolla, CA). The given number of answers were each displayed as frequency to total answers given and rounded to the nearest whole number. The survey was exempted from ethical approval by our Institutional Review Board. There are no financial disclosures.

RESULTS

The online data search retrieved the following hits: CPB and initiation (877 articles), CPB and cerebral oximetry (839 articles), CPB and cerebral blood flow (5,069 articles), heart lung machine and initiation (21 articles), heart lung machine and cerebral oximetry (269 articles), or heart lung machine and cerebral blood flow (1,652 articles). In the review of those articles, we were not able to find any studies or data sets relating to the impact of CPB initiation on patient physiology. Current studies concentrated on the impact of the CPB in principle. Further searches with adding secondary search terms provided no better results in the literature review.

In total, 78 cardiac surgery centers in Germany were contacted via e-mail and the response rate after 6 weeks was 72% (n = 56). All questionnaires were completed correctly and were included in the analysis.

The majority of perfusion departments (75%; n/total = 41/55) do not use NIRS as a standard measurement while the patient is on CPB (Table 2).

In most centers, it is reserved for clinical scenarios where cerebral perfusion might be impaired because of technical or surgical implications (Figure 1). Cardiac surgeries with a high possibility of cerebral ischemia like aortic arch surgery using selective cerebral perfusion techniques or preexisting cerebral pathologies (e.g., history of stroke and carotid artery stenosis) yielded the highest frequency of NIRS usage with 93% (n/total = 42/45) or 76% (n/total = 34/45), respectively. A less frequent use of NIRS monitoring is seen for separate cannulation of the caval veins (18%; n/total = 8/45) or femoral cannulation (22%; n/total = 17/45). Other reasons included pediatric cases (20%; n/total = 9/45), repeated heart surgery (4%; n/total = 2/45), exclusion of cannula misplacement (2%; n/total = 1/45), and total circulatory arrest (2%; n/total = 1/45). Four of the centers did not specify the reason (9%; n/total = 4/45). On the other hand, NIRS is rarely applied for regular coronary artery bypass graft (CABG) (4%; n/total = 2/45) or valve surgeries (3.8%; n/total = 2/45).

Table 1. All questions from the survey.

Number of Question	Questions
1.	Is NIRS being used with every surgical procedure involving the CPB?
2.	For what specific surgical cases is NIRS being used? Answers: Coronary artery bypass graft (CABG), valve surgery, aortic arch surgery with selective cerebral perfusion (SCP), separate cannulation SVC and IVC, femoral cannulation, cerebral pathologies (e.g., history of stroke and carotid stenosis), and other reasons (please specify).
3.	Does your center use a standard CPB start-up time for reaching the 100% flow of wanted cardiac output for the patient?
4.	What usual initiation time is used in your center? Answers: 30 seconds, 60 seconds, 90 seconds, 120 seconds, 150 seconds, and 180 seconds.
5.	Do you think that a fast CPB initiation could be potentially harmful to patients?

Table 2. Distribution of responses from the respondents to Questions 1, 3, and 5 in the survey.

Question	Yes		No		Total
	n	%	n	%	
1. Is NIRS being used with every surgical procedure involving the CPB?	14	**25.45**	41	**74.55**	55
3. Does your center use a standard CPB startup time for reaching the 100% flow of wanted cardiac output for the patient?	19	**33.93**	37	**66.07**	56
5. Do you think that a fast CPB startup could be potentially harmful to patients?	48	**85.71**	8	**14.29**	56

Bold values indicate a significant difference in the answer given ($p < .05$, chi square for trend-test.

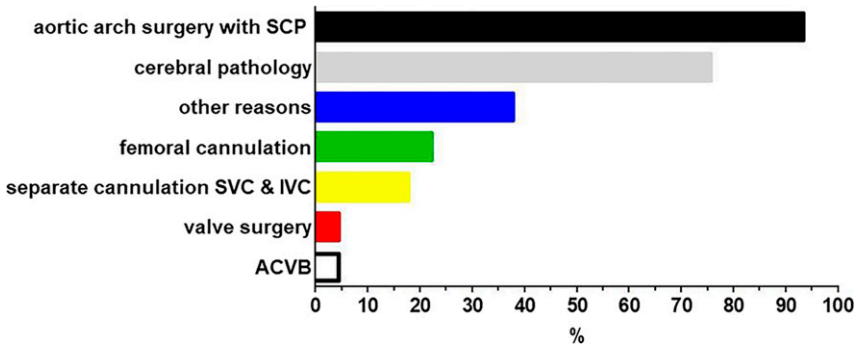

Figure 1. Distribution of responses from respondents "If you do not use NIRS for every cardiac surgery, in which cases is it used (multiple answers possible)?"

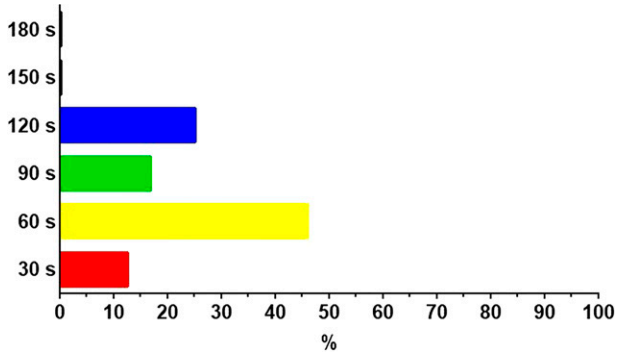

Figure 2. Distribution of responses from the respondents: "If you have a standard in the clinic, which following period is most likely to apply?"

Questions relating to the initiation of CPB (Table 2) revealed that only one-third of centers use a standardized time (34%; n/total = 19/56) for increasing the pump flow to 100% of target flow rate despite the belief of potential harm with fast initiation (85%; n/total = 48/56). The initiation times range from 30 seconds to 120 seconds (Figure 2) with a more frequent use of 60 seconds (46%; n/total = 11/24) and 120 seconds (25%; n/total = 6/24). Slower initiation times of 150 and 180 seconds are not being used.

DISCUSSION

It has been over 40 years since NIRS was introduced, but a consensus on application and clinical decision guidance of $rScO_2$ is still lacking. There is only scarce data on the actual practice of NIRS in the operating room today. Our survey tried two answer two subject matters: one is the frequency and specific NIRS usage in cardiac surgery and second is the matter on how fast CPB is initiated by the perfusionists. As we are focusing on technical CPB management, the survey included perfusion departments, knowing that it has been also shown that there are differences in the perception of its utility between cardiac anesthesiologists and perfusionists (8).

Following our survey, NIRS is not routinely used in cardiac surgery with CPB in Germany, as the majority of centers (75%) are usually using it only for specific interventions. Replacing the aortic arch yields high risk of cerebral ischemia with a stroke risk of about 3–6% (9–11). Comparing our results of aortic arch surgery with others, one can assume that the adoption of NIRS monitoring has increased over the last 10 years reaching almost 100% today compared to a poll with panelists of an aortic arch symposium in 2006 that revealed a routine use of NIRS in roughly 30% of aortic arch surgeries (12). In a 2013 survey by Zacharias and colleagues, a routine use of cerebral oxygen saturation monitoring during that procedure varied between 50% and 70% depending on with or without the use of deep hypothermic circulatory arrest (8). Additionally, their study revealed a higher routine utilization of NIRS with about 30% (anesthesiologists answer) and 50% (perfusionists answer) in all adult cardiac surgery. Infrequent use of NIRS involved indications for cannulation techniques, CABG, and valve surgeries. The lower overall frequency use in our study for pediatric cases is probably because of the small percentage of centers that perform pediatric cardiac surgery. A routine utilization of the NIRS technology in pediatric cardiac surgery is reported to be around 60% (8,13). Combining the published data with ours, it is safe to assume that NIRS is usually applied in such specific surgical cases where there is an imperative to protect the brain of ischemia, thus on the contrary, a general application for every cardiac patient with CPB is not widely performed.

One very surprising finding in our survey was the fact that although most departments think that a fast initiation of CPB could be potentially harmful to patients, only a few use a standardized time for going on bypass (Table 1). The range of the initiation times varied from 30 to 120 seconds with a majority using a moderate time of 60 seconds to start the heart–lung machine. The only recommendation on how fast or slow to go on bypass we could find so far is in the book *Cardiopulmonary*

Bypass: Principles and Practice (14), where it reads as follows: Full CPB flow can be established in most cases within 30 seconds. In a newer online NCBI bookshelf publication by Ismail and Miskolczi on CPB, no recommendation is found on the appropriate ramp up time of the heart–lung machine when going on bypass (15). Thus, we found after our thorough literature search it is safe to assume that there is no scientific evidence for recommending a specific time frame in which the CPB should be initiated to this date.

Several limitations of our survey need to be considered. Because of the anonymity of the survey and therefore lacking center demographics, it was not possibly to link the use of NIRS to the eventual case load and case mix of each center. An answering bias also cannot be excluded as only the chief perfusionist of each center was offered to take part in the survey and thus daily practice in the departments may actually differ on an individual basis. Again, for simplicity reasons, the term "initiation time" only referred to the time reaching the target flow rate without specifying its calculation (a common accepted calculation being 2–2.5 L/min $\times$ body surface area in m^2) and also the centers were not given a definition of a fast initiation time. The authors believe that an initiation time under 30 seconds should be considered as "fast," whereas a time over 120 seconds should be considered as "slow." Other technical variations of going-on bypass (e.g., different handling of venous drainage or patient filling pressures) were also not examined with our provided questions.

Despite those mentioned limitations, we believe that our survey revealed a reserved application of the NIRS technology in the German cardiac centers and even more importantly displayed a disparity between a belief of harmful fast initiation of CPB and actually applying that belief to daily practice with a standardized protocol. In a study by Ševerdija that looked into the impact of intraoperative events on cerebral tissue oximetry in CPB patients, it was clearly shown that the most significant negative change in mean cerebral $SctO_2$ happens during the onset of CPB (16) and that change persisted almost throughout the whole bypass. In conclusion, after its daily application for over 50 years, the lack of scientific studies on how to initiate a CPB is puzzling, as it resembles the first critical phase for cerebral perfusion during the whole bypass period.

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