Arterial cannulation in children: is it time for guidelines ? An international survey

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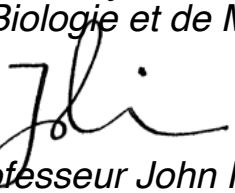

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An international survey

THESE

préparée sous la direction du Professeur Christian Kern

avec la co-direction du Docteur Gianluca Bertolizio

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DOCTEUR EN MEDECINE

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ARTERIAL LINE CANNULATION IN CHILDREN: IS IT TIME FOR GUIDELINES? AN INTERNATIONAL SURVEY

Running head: Arterial line cannulation in children
Article category: Research report

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What is already known:

- Peripheral arterial cannulation in children and infants is a common procedure, although not devoid of potential serious complications.
- Contrary to central venous line insertions there are no specific paediatric guidelines.

What this article adds:

- This article presents a snapshot of current practice in North America, Great Britain and Italy.
- There is a uniformity of practice around the radial artery as first choice for cannulation, while insertion techniques, maintenance regimens and management of failure or complications vary based on personal preferences.

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1. ABSTRACT

Background: Arterial cannulation is routinely used during major surgeries and in critically ill children; however, it is associated with rare but serious complications and paediatric guidelines are lacking.

Aims:
The aims of the survey were to describe the practical approach to paediatric arterial cannulation among members of four Paediatric Anaesthesia societies, centred on most vulnerable patients (neonates and infants) and see if there were differences related to experience or country of practice.

Methods: We conducted a web-based survey that collected information on choice of insertion site, technical preferences, utilization of Acoustic Doppler and 2-dimensional ultrasound, complications and Keep-Artery-Open regimens during arterial cannulation in children and neonates.

Results: A total of 899 of 4254 members completed the survey (21%). The majority (75%) does not have paediatric guidelines. Radial artery is the primary choice for cannulation (90%). In neonates, catheter sizes are 24G (69%) or 22G (21%) for radial, and 2.5F (38%) or 22G (30%) for femoral arteries. In case of failure, 67% of the respondents change limb.
Allen's or similar tests are often not performed (74.%). Non-transfixing and guide-wire "transfixing" techniques are equally common.
56% and 60% of the responders use acoustic Doppler and 2-dimensional ultrasound occasionally, respectively.
Complications are not uncommon (16%) and are often temporary occlusion (42%) and hematoma (33%). In case of temporary occlusion, watchful waiting is often preferred (41%). In children < 10kg, saline with or without heparin is used for catheter patency (31% and 41%, respectively).

Conclusion: Our survey confirms that the radial artery is the first choice for cannulation. However, techniques and management vary and paediatric guidelines are rare**.** Paediatric cannulation varies among anaesthesiologists. Further studies and eventually specific guidelines may be recommended.

2. INTRODUCTION

General aspects of patient's monitoring during anaesthesia

Monitoring of patient's physiological parameters and anaesthesia medical devices is a key aspect of contemporary anaesthesia and represents a field of growing interest and perpetual innovation (Sola et al., 2016). As surgical procedures and anaesthesiology has grown more sophisticated and complex, so have the monitors and the data that they produce. A proper and accurate monitoring is intimately intricate with patient's safety and promotes positive perioperative outcomes. The World Federation of Societies of Anaesthesiologists (WFSA) has adopted standards for a safe practice of anaesthesia in 1992, revised in 2008 and 2010 (Merry et al., 2010). Minimum (basic) universal physiological monitoring standards should focus on patient's oxygenation, cardiac rate and rhythm, tissue perfusion, blood pressure, and temperature (when clinically significant changes in body temperature are intended, anticipated or suspected: i.e. prolonged or complex surgeries, children) are "highly recommend" from Level 1 to 3 (i.e. small hospitals to referral centres). Those measurements are delivered by continuous pulse oxymetry, non-invasive blood pressure (at least every 5 minutes) and measuring temperature at "frequent intervals". Depth of anaesthesia, inspired and expired concentrations of oxygen, anaesthetic gases and volatile agents, capnography are only suggested for and left to level 3 centres. Many of these provisions have been transferred to recovery room (Post Anaesthesia Care Unit – PACU).

Children are a high-risk population, hence should be monitored appropriatively. Most studies have focused on the rate of cardiac arrests resulting from anaesthesia and children display a three to fivefold greater risk compared to adults (Graff et al., 1964) and factors contributing to fatalities are presumably linked to cardiovascular or respiratory systems (Salem et al., 1975). The incidence of serious complications other than cardiovascular collapse is also greater for infants than for adults in the operating room (Tiret et al., 1988) and in the PACU (Cohen et al., 1990).

Blood pressure monitoring: techniques and physiology

In this work, we will focus on blood pressure monitoring in paediatric patients, with a special interest on infants and neonates. Blood pressure has been first measured by auscultation, based on the "five Korotkoff sounds" method, named after Dr Nikolai Korotkoff, a Russian physician who described them firstly in 1905. Those sounds represent the turbulences created by the inflation and deflation of a manually air filled cuff, aiming for a complete occlusion of the blood flow. Traditionally, the first sound to appear during cuff deflation delineates the systolic blood pressure and the diastolic pressure by the fourth sound (distinct abrupt muffling of sounds) or the fifth sound (i.e. auscultatory silence). This auscultatory method is 100% manual and subject to inter- and intra-individual variations. Looking for automatization and more objective measurements, the oscillotonometry method has been

developed, a technique that relies on the detection of small oscillations variations created by the deflation of a cuff, initially inflated at a pressure in excess of systolic arterial pressure. The cuff pressure is monitored by a pressure sensor and will read the cyclic expansion and contraction of the measured artery (ex. brachial, radial or tibial), i.e. will oscillate. An algorithm that deducts the systolic, diastolic and mean arterial pressures will then analyze the oscillation curve. Other non-invasive methods exist, like “Pulse Wave Velocity” or “CNAP Device®” (continuous non-invasive arterial pressure using finger cuff) that allow continuous monitoring but are beyond the scope of this article. The inaccuracy and imprecision of those non-invasive techniques are still larger than what was accepted and minimize their use in daily practice (Kim SH et al., 2014), however the technology is improving rapidly (Sola J et al., 2016). Of note, paediatric experience with such devices and technologies is still scarce and limited to studies with small cohorts, but tends to show a positive future trend (Kako H et al., 2013), limited up to know by technical contingencies (Andriessen P et al., 2008).

The accuracy of monitored data is of paramount importance and depends on the device, the technology and the site of measurement that is used. Up to now the “gold standard” still relies on invasive intra-arterial monitoring for three reasons. Firstly, all non-invasive blood pressure monitoring deviate from invasive values by varying extent but always underestimate the systolic by a average of 15 mmHg and overestimate the diastolic component of blood pressure by 8 mmHg (Finnie KJ et al., 1984). Secondly, non-invasive methods are limited and often not functional when the patient present unstable hemodynamics or rhythm irregularities as those conditions will prevent proper measurements. Thirdly, the pathological conditions of some patients may induce the failure or inability to use indirect blood pressure monitoring, such as severe burns patients, dialysis grafts or shunts, or morbidly obese.

For all these reasons, direct, invasive blood pressure monitoring is indicated every time when there is a need for continuous and precise beat-to-beat blood pressure monitoring, like cardiac surgery, anticipated hemodynamic alterations related to blood loss, fluid shifts, etc. Last but not least, direct arterial access allows to draw arterial blood sample, which is important for blood gas monitoring, acid-base determination and patient’s perioperative acute management in case of pre-existing or anticipated abnormalities in gas exchange (f.ex. pre-existing pulmonary disease or procedures impacting gas exchange like thoracotomies).

Invasive blood pressure monitoring by arterial catheters: epidemiology, techniques and complications

Arterial catheters are used in the operating room for continuous hemodynamic monitoring and blood samplings. Approximately 2.5 to 8 million arterial catheters are inserted in Europe and USA each year (Scheer B et al., 2002. Lorente L et al., 2006.). The success of this relatively common procedure relies on multiple factors, some of them being more relevant: pre-procedural (contingencies linked to patients and surgical plan, site of insertion, sterile precautions), periprocedural (choice of cannulation, technique of insertion, device to assist cannulation) and post-procedural factors (maintenance regimens, troubleshooting of complications).

There are no absolute contraindications to insert an arterial cannula, but a risk-benefit analysis should be performed. Arterial cannulation at any site has been associated with complications, like ischemia, necrosis, haemorrhage, hematoma, or infection (Scheer B et al., 2002; Schindler E et al., 2005.). These complications are more frequent and severe in small children and infants than in adults (Smith-Wright D et al,. 1984; Dumond AA et al., 2012) mainly for two reasons. Firstly because the arteries are smaller hence more prone to occlusion in case of thrombus or compressive hematoma, secondly because cannulation of infants and neonates arteries is technically more challenging than in older children or adults. The rate of failure or the need for multiple attempts is thus higher in the paediatric population. Moreover, it is a widespread experience that some categories of paediatric patients are even more demanding during vascular catheterization, like children with Down syndrome (Sulemani DS et al., 2009) or paediatric patients with congenital cardiac conditions (Schindler E et al., 2005).

Technologies to improve arterial cannulation success

Amongst various technical solutions to increase first attempt success, 2-dimensional ultrasound (2D US) has been reported to be helpful, thus decreasing the rate of complications associated to multiple attempts (Gao YB et al,. 2015; Aouad-Amroun M et al., 2016).
However, 2D US for arterial cannulation is a recent trend and neither its rate of utilization among paediatric anaesthesiologists nor its degree of implementation in decision algorithms is known, for example in case of technical difficulties. The effect of age and expertise in the use of 2D US by paediatric anaesthesiologists may play a role but is also not known to what extent.

Sites of arterial cannulation and pre-cannulation evaluation

Regarding the site of cannulation, the choice seems to be mostly based on individual preferences (Akpek EA et al., 2008). The radial artery is the most commonly used vessel for cannulation, since it is considered safe due to the presence of the collateral ulnar blood supply (Smith-Wright D et al., 1984 ; Williams D et al., 200) and also because the vessel lies superficial and easily accessible. Other popular cannulation sites are the ulnar, femoral, tibialis posterior or dorsalis pedis arteries. Less frequently used sites are the axillary and the brachial ones. Of note, the axillary artery has gained popularity because of higher collateral blood flow compared to brachial or femoral (Piotrowski and Kawczynski 1995; Schachner T et al., 2005) arteries.
At the forearm, the patency of this collateral circulation has been assessed with a test firstly described by a physician named Edgar Van Nuys Allen who was looking for a non-invasive evaluation of the patency of the arterial supply to the hand of patients with thromboangeitis obliterans (Allen EV 1929). The originally description consisted of a parallel clenching of both fists during one minute, then simultaneous compression of both ulnar or radial arteries a the

wrist. The test compared the return of hands coloration and the initial “pallor” be replaced quickly by “rubor” (redness due to blood recirculation and release of vasoactive mediators due to tourniquet physiology). Irvine Wright described a modification of this test in 1952, to evaluate one hand before arterial cannulation: after elevation of the hand, the patient is asked to clench the fist for 30 seconds and the physician applies simultaneous compression on both radial and ulnar arteries before the patient is asked to reopen the hand. Then the physician releases the compressions only over the ulnar artery and the initial general “pallor” of the palm should be replaced by colour within 5 to 15 seconds. If not, the test is declared abnormal (positive), suggesting that the ulnar supply to the hand is not sufficient, thus indicating that a cannulation of the radial site may not be safe. Since then, this test has been applied for decades before cannulating arteries at the forearm.

However, its utility has recently been brought into debate (Habib J et al., 2012). Firstly, there is no consensus regarding the optimum cut-off time for positive test, secondly it appears that the test is unable to provide a clear cut-off point below which perfusion can be deemed vulnerable and studies show conflicting results. Moreover, there have been severe ischemia requiring amputation in patients showing negative (normal) tests, on the opposite, patients with positive (abnormal) test have not developed signs of ischemia (Benit E et al., 1996).
Although the overall diagnostic accuracy with the 5-seconds threshold may show some improvement (sensitivity of 70-75% and a specificity of 80%-90%) in adults depending on the method used, modified, enhanced or traditional (Kohonen M et al., 2007), nevertheless the evaluation of collateral circulation prior arterial cannulation is difficult to implement in the practical settings and vary depending on patient’s characteristics (cold vasoconstriction, etc.) and is highly subject to interrater variability.
Finally, specific paediatric studies are scarce (Mercier FJ et al.; 1994).

The aims of the survey were to describe the current practical approach to paediatric arterial cannulation among anaesthesiologists in North America and Europe, cantered on most vulnerable patients (neonates and infants, 3 clinical scenarios). Indeed, there may be a relative large discrepancy between recommendations of practice based on studies and the effective implementation in the daily practice. Such discrepancies may be related to age of practitioners, year of experience, expertise or region of practice.
Regarding the three different procedural steps, we have specifically addressed as primary endpoints, the descriptive analysis of:

1) The techniques of arterial line cannulation:
    i. Implementation of sterile precautions/written guidelines;
    ii. Preferred site of arterial catheterization and rational for its use;
    iii. Second option in case of failure on the first choice;
    iv. Use of Allen’s tests;
    v. Catheter size and device used in neonates;
2) The utilization of Doppler and 2D ultrasound guidance;
3) The utilization of troubleshooting strategies in case of failure or complications.

The secondary endpoints were the comparative analysis between:

1) Countries and/or regions of Europe and North America;
2) Experienced anaesthesiologist (>15 years of practice, >24 arterial line per year placed, staff position) and the less experienced ones (<16 years of practice, <25 arterial line per year placed, fellow position).

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3. METHODS

3.1. Introduction on web-based surveys and methodology

Context:

Survey research is an important adjunct to scientific inquiry and may help refine the impact of clinical research on practice by questioning, for example, clinicians about their knowledge, attitudes and practices. However this type of research merits rigorous design and analysis, in order to ideally gather reliable and unbiased data from a representative sample of respondents (Fink A; 2002).

On the different methods to conduct survey research, web-based surveys ("e-surveys") have emerged as an affordable window into the world of practitioners, by allowing electronic fast distribution and anonymous collection of data from a target audience in a time-efficient and economical way, especially when dealing with large sample population. E-surveys ma be part of a qualitative research process, but results ca be analyzed quantitatively as long as researchers are aware of potential bias (Eysenbach G et al., 2002).

Design:

A clear objective is essential and needs a thorough review of the literature in order to refine the topic and develop primary and secondary research questions.

Target population:

The "sampling frame" is defined as the target population from which the sample will be drawn (Burns K.E.; et al. 2008). Sample selection can be random or deliberate, as in our study. Indeed, surveys that use membership lists and refer to smaller component of anaesthesia societies (for example SARNePI or CPAS from the Italian Society of Anaesthesia or the Canadian Society of Anaesthesia) may be sent to all members. This sampling technique refers to "convenience sampling", as opposed to "probability sampling", which may be necessary to employ in case of larger parent societies or target population, but more complicated to implement.

After determining the sample frame, comes the "sample size", which refers to the amount of respondents necessary to produce robust findings. The more the better, however there are some techniques to estimate that number. Firstly as a rule of thumb, according to some researchers a minimum sample size of 100-500 is sufficient for most surveys (MacCallum R et al., 1999). Secondly, more robustly, after drawing the sample size, a confidence level and interval should be established, there are online calculator to ease that calculation.

Potential bias:

Survey research suffer from some specific bias, mainly of three types:

- *Self-report or social desirability bias*: respondents may deliberately exaggerate characteristics or behaviours that could induce, respectively, positive or negative individual's evaluation.
    - *Anonymization of questionnaires will help participants to answer honestly*.
- *Recall bias*: when relying on information that occurred in a distant past, respondents may have difficulties to precisely remember a situation and tend to answer as a guess more than a fact.
    - *Consider shorter time references (for example: last month rather than two years ago).*
- *Non-response bias*: the greater the response rate, the more likely the data will be representative. Some advocate a 70% response rate for external validity and robust statistics (Burns KEA et al., 2008), however there is no set standard of what represent a good response rate. The main concern with non-response bias is that the nonrespondents may be in some way different from respondents and bias the results.
    - In order to mitigate that important bias, the number of question should be limited to 20-25 maximum, the survey should be well written and include an encouraging cover letter. Finally, e-mail reminders should be well organized, usually recommended at 2, 4 and 8 weeks following the initial survey distribution (Dillman D. 2007).

Items development:

Regarding questions, there are mainly two types: either "open" (free text box) or "closed" (structured) with predefined format answers that can include binary (yes/no), nominal, ordinal and interval or ratio measurements. Closed questions that request respondents to rank items need a specific design and should adopt a neutral tone in order to avoid influence on respondents' answer.

Pilot test and retest:

Once the questionnaire has been developed, it should be tested with a small sample of people, usually similar to the target population, in order to address any technical issue (problems with the website or the branching and ordering of questions for example), flow and dynamic between questions or any language incoherency that would preclude a correct understanding of the survey. This test phase may be done twice, in order to assess the reliability of question and interrater variability.

During that pilot phase it is also important to assess the time taken to complete the entire survey as a too long questionnaire will increase the dropout rate.

Ethical issues and privacy protection:

Ethical issues should not be let aside and include informed consent, Institutional Review Board (IRB) approval and protection of privacy, all basic stones of scientific research on human populations (practitioners / medical staff are human populations as well).

In order to minimize one of the major bias of e-surveys that is non-response, some research group use "cookies" to track IP addresses, avoiding on one hand multiple answers and on

the other hand providing a way to specifically re-address recall questionnaires. However, there is some ethical issue with electronic tracking directed towards privacy protection that is balanced with the issue of less robust data in case of low response rate and the impossibility to target recall questionnaires to nonrespondents.
Another issue addressing privacy protection is the resort to emails address books, either private or professional. A way to circumvent that bias is to address the questionnaire to target population through their respective professional societies (for example paediatric anaesthesia societies), in the end no private or professional email address are disclosed to research groups.
Finally, when reporting results, the total anonymity of research participants needs to be guaranteed.

Administration:

Internet e-surveys pose unique technical challenges and methodological concerns (Braithwaite D et al., 2003). Electronic software is required for questionnaire development and analysis; otherwise commercial electronic survey services can be used (for example: SurveyMonkey© or QuestioPro© that are currently amongst the most popular websites). An electronic cover letter should closely precede the delivery of e-questionnaires. Internet based surveys present a slightly lower response rate than postal administration, but allow fast analysis of results and low global costs.

3.2. Reporting of survey research, statistics and sample size calculation

Reporting guidelines:

Reporting results of e-surveys has been improved by using guidelines or checklists, as the CHERRIES one: CHEcklist for Reporting Results of Internet E-Surveys (Eysenbach G, 2004).

Sample size calculation and response rate:

There are different methods to estimate the sample size, like looking for 10-20 respondents per item, as seen before a rule of thumb of 100-500 respondents is deemed sufficient by some researchers (MacCallum R et al., 1999) or one may use calculators found on some websites (f. ex.: https://www.surveysystem.com/sscalc.htm). Based on that site, admitting a confidence level of 95%, a confidence interval of 5% with a total population of 4254 questionnaires sent, the sample size needed was 352 answers.

Of note, the desired response rate should generally approach 60-70% for external validity, although physicians tend to perform lower than non-physician, with a mean response rate of 54% and 61% respectively (Cummings SM et al., 2001).

Usually, surveys use descriptive statistics for reporting results.

3.3. Survey on arterial line: design and method

We conducted an anonymous, cross-sectional, web-based international survey among paediatric anaesthetists of United States, Canada, Italy and the United Kingdom between July 2014 and December 2014.

The Institutional Review Board of the McGill University Health Centre approved the study (IRB Nr 13-451-PED). It was then reviewed by the boards of each respective paediatric anaesthesia society: the Canadian Paediatric Anaesthesia Society (CPAS), the Society of Paediatric Anaesthesia (SPA), the Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) and the Società di Anestesia e Rianimazione Neonatale e Pediatrica Italiana (SARNePI). Each board received a detailed presentation of the survey, its aims, questionnaire, ethical considerations (no tracking IPs, possibility to withdraw at any time, guarantee of anonymity) and Internet link to the survey website.

Each society was asked to send 3 reminders at 1 week, 3 and 7 weeks. According to their own guidelines on survey research the APAGBI sent only 2 reminders at 1 and 7 weeks.
The questionnaire was designed according to previously published guidelines (Burns KEA et al., 2008; Schleyer T et al., 2000; Tait AL et al., 2015).

- Sampling frame: non probability design, purposive sampling (members of paediatric anaesthesia societies)
- Item generation: research questions suggested through literature reviews
- Item reduction: questions reduced to 26, in order to avoid a lengthy questionnaire and to improve the response rate
- Questions stem: contained ideally fewer than 20 words (except the three clinical scenarios) to improve understanding and interpretation. For example, we adopted a neutral tone for questions requesting respondents to rank items but were more demonstrative for questions waiting for binary responses. Some questions we felt important were designed to be compulsory to answer in order to continue through the questionnaire, otherwise it was possible to skip to the next item. Boxes of free expression were left open depending on the question
- Reminder strategy: according to Dillman and colleagues a 3 follow-up “waves” was designed at 1 week, 3 and 7 weeks. To respect privacy of each society’s members we didn’t have a direct access to their respective mailing list. Consequently the anaesthesia societies sent the survey’s e-link directly to their members.
- Administration: we chose to follow an entire internet-based survey, for practical reasons (budget, rapidity of overseas communication, target group accustomed to internet technologies and for being contacted by email as a preferred mode of communication).
- Cover letter: sent to all societies, with an explanation and aims of the study, which was also included on the first page of the study with a possibility to deny participation.

- Consent and ethical considerations: survey completion was voluntary and responders and their institutions remained anonymous. No personal information was required, but responders might voluntarily leave their email address if they were willing to be contacted for more information or feedback. In case of publication of the survey, data would remain strictly anonymous.
- Testing of the questionnaire: first, we tested the survey with different computer interfaces (PC, tablets, PDA), operating systems, Internet browsers and type of Internet access (high-speed local area network and modem dial-up line). Then, 16 paediatric anaesthesiologists (14 staff physicians and 2 fellows) completed the survey twice in a 3-week period.

The pilot test initially showed a bug in the branching questions not allowing the completion of the survey. A second version did not uncover any further technical problems. After confirming the consistency of the answers and reviewing the feedbacks, the questionnaire was uploaded on the website "Question Pro" (www.questionpro.com) under the Montreal Children's Hospital Department of Anaesthesia's account.

The survey was anonymous; participants were required to confirm their consent to participate, and could quit the questionnaire anytime. The survey included 26 questions (Appendix 1): 23 core questions, two branched questions, and one free comment:

- **Questions #1-7** collected general information regarding participants' professional background.
- **Questions #8-18** investigated clinical and technical preferences regarding the arterial cannulation. Three clinical scenarios related to a full term 1-month old baby were also presented (**questions #10-12**).
- **Questions #19-22** addressed information on complications related to cannulation and Keep Artery Open (KAO) infusion regimens in infants.
- **Question #23** consisted of a free comment box and the possibility to leave an email address in case the participant was willing to receive the survey's results.

Data were analyzed with descriptive statistics and reported as a percentage and 95% confidence intervals. We compared the use of 2D US and the incidence of complications with the number of arterial catheters inserted per year, with the experience of the anaesthesiologist, and with the days per week worked in the paediatric operating room.
Dichotomous data were analyzed using McNemar's test and ordinal data using the Kruskal-Wallis test. A p-value <0.05 was considered statistically significant. The analysis was performed using the SPSS software (version 23; SPSS, Inc., Chicago, IL).

3.4. Survey questionnaire in extenso

PEDIATRIC ARTERIAL LINE SURVEY (Question Pro Website)

Introduction text

1. Dear colleague,
You are invited to participate in our survey "Pediatric Arterial Line Survey" , promoted by the Department of Anesthesia of the Montreal Children's Hospital. It will take 10 to 15 minutes to complete this questionnaire. The aim of this survey is to describe the clinical and technical approach to arterial cannulation among pediatric anesthesiologists of Canada, United States, Great Britain and Italy. It is very important for us to learn from your opinions.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. You can also skip most of the questions if you do not want to answer; only a few of them are mandatory (marked with an "*").

Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate, they will be coded and will remain confidential. No personal information will be asked. Data will be stored in a password secured database at the Montreal Children's Hospital for 5 years. Aggregate results will be circulated to all participants upon completion of the study.
If you have any questions about the survey you may contact Dr. Gianluca Bertolizio at 1-514-413-4400 ext 22464. Or by email at gianluca.bertolizio@mcgill.ca.

Thank you very much for your time and support. After checking the box below, please start with the survey by clicking on the "Continue" button below.

☐ **By checking the box, I agree to participate to the survey**

Question 1

"What is your current position?"

- ○ Staff
- ○ Fellow
- ○ Resident
- ○ Other (please specify)

Question 2

"In what kind of institution do you work most of the time?"

- ○ Pediatric University Hospital
- ○ University Hospital Mixed Activity (i.e., pediatric and adult activity)
- ○ General Hospital Mixed Activity (i.e., pediatric and adult activity)
- ○ Private Clinic
- ○ Other (please specify)

Question 3

"Please provide the Province / State / Country of your medical practice"

-- Select --

Question 4

"How often do you practice paediatric anaesthesia in the operating room per month?"

- ○ < 4 days per month (one day per week)
- ○ 4-8 days per month (two days per week)
- ○ 8-12 days per month (three days per week)
- ○ 12-16 days per month (four days per week)
- ○ > 16 days per month (everyday practice)

Question 5

"How many years of experience do you have in paediatric anaesthesia?"

- ○ 0-5
- ○ 6-10
- ○ 11-15
- ○ 16-20
- ○ > 20

Question 6 *

"How often do you place arterial lines in children?"

- ○ Never
- ○ Very occasionally (1-5 per year)
- ○ Less than one per month (6-12 per year)
- ○ Between one and two per month (13-24 per year)
- ○ More than two per month but less than one per working day (25-42 per year)
- ○ More than one per week (more than 42 per year)

Question 7

"Do you have local written guidelines for arterial cannulation (i.e. technique, dressing, sterile precaution)?"

- ○ no
- ○ yes (if possible, please specify) [ ]

Question 8

"What medical device do you usually prefer for arterial cannulation in paediatric patients?"

- ○ Venous cannula (i.e., Jelco, etc.)
- ○ Specific arterial cannula (please specify) [ ]

Question 9

"How often do you use the following sites as first choice for arterial cannulation? (5 stars = most of the time; 1 star = least of the time)"

Ask/perform a cut-down (any site)	☆ ☆ ☆ ☆ ☆
Axillar	☆ ☆ ☆ ☆ ☆
Brachial	☆ ☆ ☆ ☆ ☆
Dorsalis pedis	☆ ☆ ☆ ☆ ☆
Femoral	☆ ☆ ☆ ☆ ☆
Radial	☆ ☆ ☆ ☆ ☆
Tibialis posterior	☆ ☆ ☆ ☆ ☆
Umbilical artery (when	☆ ☆ ☆ ☆ ☆

* Questions marked with * were compulsory to answer in order to continue the questionnaire further on

appropriate)	☆ ☆ ☆ ☆ ☆
Ulnar	☆ ☆ ☆ ☆ ☆

Question 10 ("baby scenario 1")

"Assuming that you need to put an arterial line in a full term 1 month old baby with all arterial sites equally available (no specific concerns related to surgery or patient's disease), please mark your preferred sites of cannulation (up to five)?"

	First choice	Second choice	Third Choice	Fourth choice	Fifth choice	N/A
Ask/perform a cut-down (any site)	O	O	O	O	O	O
Axillar	O	O	O	O	O	O
Brachial	O	O	O	O	O	O
Dorsalis pedis	O	O	O	O	O	O
Femoral	O	O	O	O	O	O
Radial	O	O	O	O	O	O
Tibialis posterior	O	O	O	O	O	O
Ulnar	O	O	O	O	O	O

Question 11 ("baby scenario 2") *

"In case you put a radial arterial line in a full term 1 month old baby, what size would you choose?"

- O 26 Gauge iv catheter (i.e., Jelco, etc.)
- O 24 Gauge iv catheter (i.e., Jelco, etc.)
- O 22 Gauge iv catheter (i.e., Jelco, etc.)
- O Specific arterial cannula (please specify) _____

Question 12 ("baby scenario 3") *

"In case you put a femoral arterial line in a full term 1 month old baby, what size of catheter would you use?"

- O 24 Gauge iv catheter (i.e., Jelco, etc.)
- O 22 Gauge iv catheter (i.e., Jelco, etc.)
- O 2.5 Fr 5 cm
- O 2.5 Fr 8 cm
- O 3 Fr 5 cm
- O 4 Fr 8 cm
- O Other (please specify) _____

Question 13

"When you decide to change site because unsuccessful at the primary site (arterial supply not compromised after cannulation attempts), what would you do?"

* Questions marked with * were compulsory to answer in order to continue the questionnaire further on

- Staying at the same level, same limb (i.e., radial vs ulnar or posterior tibial vs dorsalis pedis)
- Changing level, same limb (i.e., radial vs brachial or axillar)
- Changing to controlateral limb (any site)
- Changin from upper limb to lower (or vice-versa)
- Prepare for cut down (any site)

Question 14

"In cooperative patients and prior to arterial puncturing at radial/ulnar level, do you assess the collateral perfusion (most of the time)?"

- o Classical Allen's test (clenching the hand, THEN digital compression of both ulnar and radial arteries, THEN opening the hand and release the pressure on ulnar artery, measure the reperfusion time)
- o Modified Allen's test (digital compression of both ulnar and radial arteries, THEN clenching and opening the hand, THEN release the pressure on ulnar artery followed by the radial artery, measure the reperfusion time)
- o Enhanced modified Allen's test (i.e., acoustic and/or color Doppler to evaluate reperfusion adequacy, plethysmography, saturometer during classic Allen's test)
- o No testing
- o Other (please specifiy)

Question 15

"What technique do you use most of the time to cannulate the artery in an infant (percutaneous approach)?"

- o "Going through the posterior wall and draw back until backflow of blood is seen", then thread OVER a wire (Seldinger technique)
- o "Going through the posterior wall and draw back until backflow of blood is seen", then thread WITHOUT a wire
- o " Puncturing and threading the cannula (without hitting the posterior wall)" OVER a wire (Seldinger technique)
- o " Puncturing and threading the cannula (without hitting the posterior wall)" WITHOUT a wire
- o I do not use a specific technique
- o Other (please specify)

Question 16 *[*]

"To locate the artery, what technique do you use most of the time?"

- o Anatomical landmarks and/or palpation
- o Doppler Ultrasound (acoustic signal) before the puncture (pre-procedural scan only)
- o Puncture assisted with Doppler Ultrasound (changes in acoustic signal during arterial puncturing; real time scan)
- o 2D Ultrasound (anatomy displayed on screen in 2 dimensions) before the puncture (pre-procedural scan only)
- o Puncture assisted with 2D Ultrasound (visual real time needle tracking, in plane or out of plane)
- o Other (please specify)

Question 17 *[*]

"How often do you use Doppler Ultrasound (acoustic signal) to assist arterial line

[*] Questions marked with * were compulsory to answer in order to continue the questionnaire further on

placement?"

- ○ Most of the time
- ○ Never
- ○ Occasionally

Question 18 (branching Q17 – answer "Most of the time")

"You use Doppler (acoustic signal) "Most of the time" for arterial cannulation in children because) multiple answers possible"

- ☐ It is superior to other techniques to detect anatomical variations
- ☐ Teaching interest
- ☐ The learning curve is faster than with other techniques
- ☐ I have a higher success rate to cannulate the artery than with other techniques
- ☐ I need less time to cannulate the artery than with other techniques
- ☐ Other (please specifiy)

Question 19 (branching Q17 – answer "Never")

"You "Never" use Doppler (acoustic signal) for arterial cannulation in children because) multiple answers possible"

- ☐ I do not have the appropriate experience/training to use Doppler for arterial line placement
- ☐ I do not have access to Doppler in our department
- ☐ In my clinical practice Doppler for arterial line placement does not offers any advantages over other techniques
- ☐ Other (please specify)

Question 20 (branching Q17 – answer "Occasionally")

"You "Occasionally" use Doppler (acoustic signal) for arterial cannulation in children because) multiple answers possible"

- ☐ I use it as a rescue technique in case of failure with other techniques
- ☐ I use it when I don't palpate the pulse or recognize landmarks
- ☐ It decreases the number of subsequent attempts of cannulation
- ☐ I use it as a teaching tool to locate the artery
- ☐ Other (please specifiy)

Question 21 *

"How often do you use 2D (2 Dimensions) Ultrasound to assist arterial line placement?"

- ○ Most of the time
- ○ Never
- ○ Occasionally

Question 22 (branching Q21 – answer "Most of the time")

"You use 2D Ultrasound "Most of the time" for arterial cannulation in children because (multiple answers possible)"

* Questions marked with * were compulsory to answer in order to continue the questionnaire further on

- ☐ It is superior to other techniques to detect anatomical variations
- ☐ Teaching interest
- ☐ The learning curve is faster than with other techniques
- ☐ I have a higher success rate to cannulate the artery than with other techniques
- ☐ I need less time to cannulate the artery than with other techniques
- ☐ I use it to measure the diameter of the artery to choose which catheter size to insert
- ☐ Other (please specify)

Question 23 (branching Q21 – answer "Never")

"You "Never" use 2D Ultrasound for arterial cannulation in children because (multiple answers possible)"

- ☐ I do not have the appropriate experience/training to use 2D Ultrasound for arterial line placement
- ☐ I do not have access to the 2D Ultrasound in our department
- ☐ In my clinical practice 2D Ultrasound for arterial line placement does not offers any advantages over other techniques
- ☐ Other (please specify)

Question 24 (branching Q21 – answer "Occasionally")

"You "Occasionally" use 2D Ultrasound "Most of the time" for arterial cannulation in children because (multiple answers possible)"

- ☐ I use it as a rescue technique in case of failure with other techniques
- ☐ I use it when I don't palpate the pulse or recognize landmarks
- ☐ It decreases the number of subsequent attempts of cannulation
- ☐ I use it as a teaching tool to locate the artery
- ☐ Other (please specify)

Question 25

"In the past two years, did you experienced complications related to arterial line cannulation from the time of its placement to its removal?"

- ○ Yes
- ○ No
- ○ I prefer not answering

Question 26 (branching Q25 – answer "Yes")

"What type of complications related arterial cannulation did you experience (multiple answers possible)?"

- ☐ Hematoma
- ☐ Localised Infection
- ☐ Nerve injury
- ☐ Permanent occlusion (severe ischemic damage)
- ☐ Temporary occlusion (blanching)
- ☐ Thrombosis / Embolism
- ☐ None
- ☐ Other (please specify)

Question 27

"What would you usually do in case of blanching of the extremity just after an uneventful cannulation (multiple answers possible)?"

- ☐ Administer a bolus of heparin (please specify the amount of units under "other")
- ☐ Administer a small dose of lidocaine to resolve the most likely vasospasm
- ☐ Administer a small dose of papaverine to resolve the most likely vasospasm
- ☐ Increase the rate/amount of heparin in the pump
- ☐ Remove the cannula immediately
- ☐ Wait and monitor the extremity with O2 saturation (look for arterial wave and saturation)
- ☐ Warm the extremity
- ☐ Other (please specify)

Question 28

"What solution and/or concentration of heparin do you use to keep patent the arterial line (KVO) in children < 10 Kg?"

- ○ Normal Saline
- ○ Heparin < 1 UI/ml
- ○ Heparin 1 UI/ml
- ○ Heparin 2 UI/ml
- ○ Heparin > 2 UI/ml
- ○ Other (please specify)

Question 29

"Please indicate the minimal rate of infusion you run to keep the arterial line patent (ml/h) in children < 10 Kg?"

- ○ 0.5 ml/h
- ○ 1 ml/h
- ○ 2 ml/h
- ○ > 2 ml/h
- ○ Other (please specify)

Question 30

"Thank you for taking part to this survey. Do you have any comments /suggestions regarding it?"

1
2
3

3.5. Survey flowchart

2014 March - April	Design of questionnaire --- Montreal Children's Hospital Department of Anesthesia --- McGill University (MCH)				
	↓				
2014 May	Test of questionnaire among staff anesthesiologists (MCH)				
	↓				
2014 June	Correction and final version of questionnaire				
	↓				
	Contact with pediatric anesthesia societies and letters of invitation sent with the internet link to the questionnaire (www.questionpro.com)				

2014 July - December	**SPA** Society for Pediatric Anesthesia	**APAGBI** Association of Paediatric Anaesthesists of Great Britain and Ireland	**SARNePI** Società di Anestesia e Rianimazione Neonatale e Pediatrica Italiana	**CPAS** Canadian Pediatric Anesthesia Society
T0	Questionnaire	Questionnaire	Questionnaire	Questionnaire
1 week	1st reminder	1st reminder	1st reminder	1st reminder
3 weeks	2nd reminder	-----	2nd reminder	2nd reminder
7 weeks	3d reminder	3d reminder	3d reminder	3d reminder

2015 - 2016	Analysis of results --- QuestionPro Website --- Writing of article

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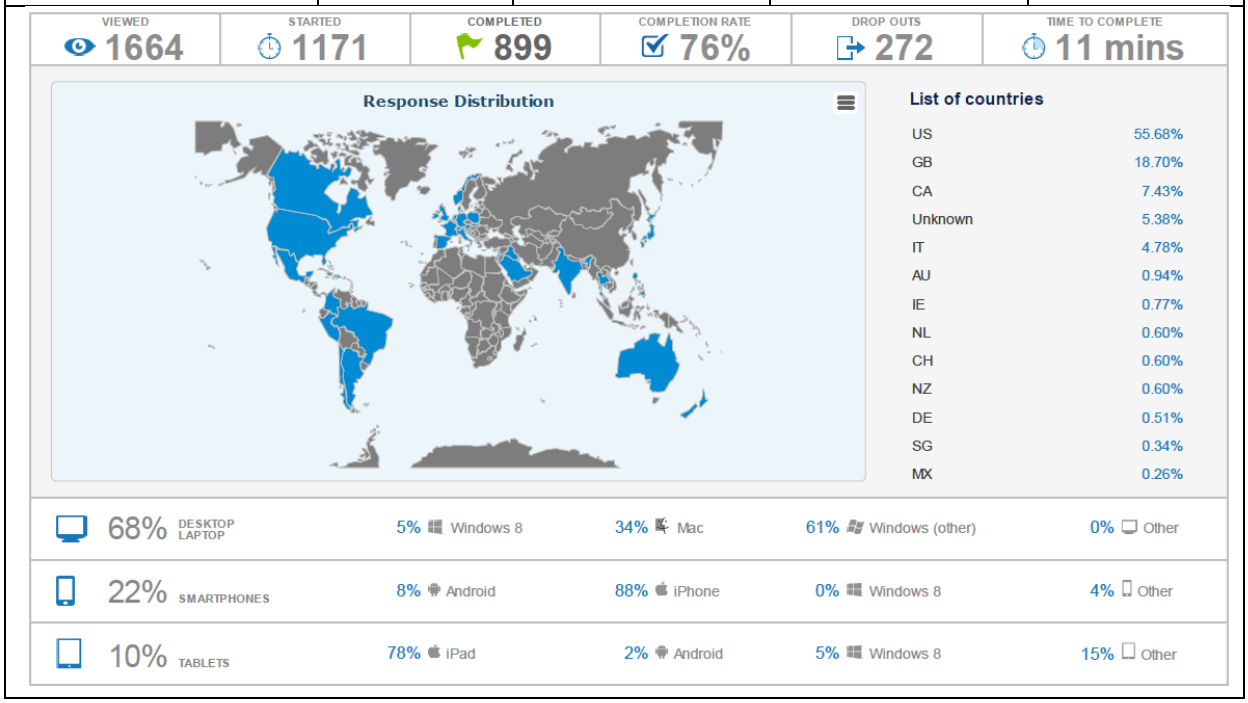
4. RESULTS

4.1. Overall results

The CPAS, SPA, APAGBI and the SARNePI invited a total of 4254 members to participate in the survey between July and December 2014. One thousand and seventy-one responders (28%) started the questionnaire, and 899 (21%) completed the survey. We analyzed only completed questionnaires.

Survey statistics Report (Time stamp 02 Mar. 2015)[1]

Questionnaires	Count	Completed / Started	Completed / Viewed	Started / Viewed
Sent	**4254**			
Completed	**899**	**76.77%**	54.03%	
Started	1171			70.37%
Viewed	1664			



Response rate by societies

Society	Number of answers			Number of members	
SPA	608	21.96%		SPA	2768
APAGBI	203	18.90%		APAGBI	1074
CPAS	55	21.23%		CPAS	259
SARNePI	33	22.22%		SARNePI	153

[1] [1] Graphics extracted from www.questionpro.com

Overall response rate	**899**	**21.08%**		**All questionnaires**	**4254**

Demographics: provenance and experience

Over half of the responders practiced in North America (USA 60%, Canada 8%, Great Britain 13% and Italy 4%). The majority of responders (90%) were staff: 81% worked in a university-affiliated hospital with only paediatric activity (54%) or combined adult/paediatric population (27%); the rest operate in a non-university hospital (12%), private clinic (1%) or did not specify (7%).

Most of the responders had more than five years of experience as paediatric anaesthesiologist (78%), performed paediatric anaesthesia at least three days per week (85%), and placed more than 25 arterial lines per year (51%).

Guidelines for arterial line insertion

Only one-quarter (25%) of responders had institutional guidelines for arterial cannulation, which often endorsed a full sterile preparation for the arterial cannulation (63%) as derived from remarks left in the free comment box allocated to that question.

Regarding devices and material, the majority of responders (77%) used regular venous catheters instead of specific arterial catheters.

Sites of cannulation and preferences

The radial artery represented the preferred site of cannulation in 90% of cases, followed by the femoral, dorsal pedis and tibialis posterior arteries (**Figure 1**).

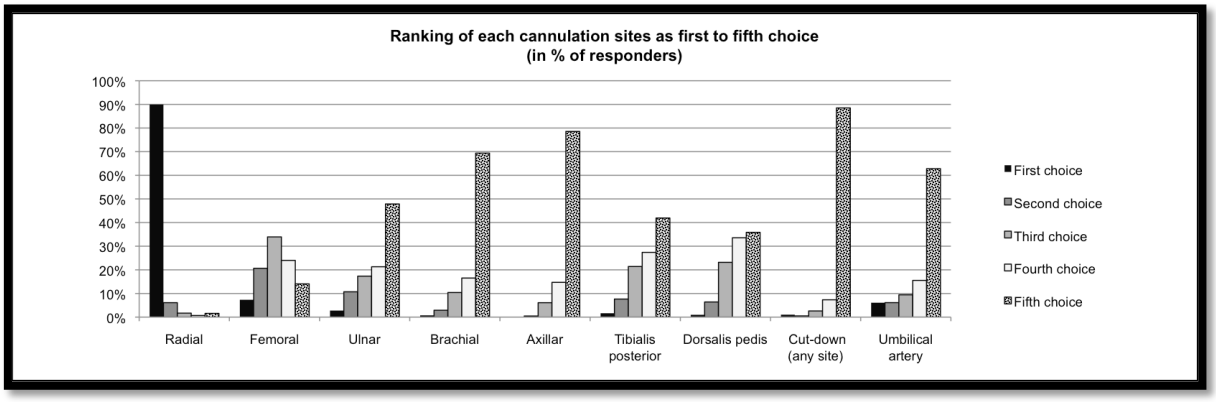


Figure 1. Favourite sites for arterial cannulation in children. Interviewers were asked to score how often the use the several arterial sites (form 1=least of the time to 5= most of the time). Cut-down was intended to either performed by the anaesthesiologist or the surgeon. Umbilical artery was intended only when available.

"Baby scenarios"

In 1-month old full term babies, the radial artery remained the first choice, followed by the femoral artery (**Figure 2A**). The radial artery was most frequently cannulate with either 24G or 22G intravenous (i.v.) catheters (**Figure 2B**), whereas 2.5Fr or 3Fr 5 cm arterial catheters were often used for the femoral site (**Figure 2C**).

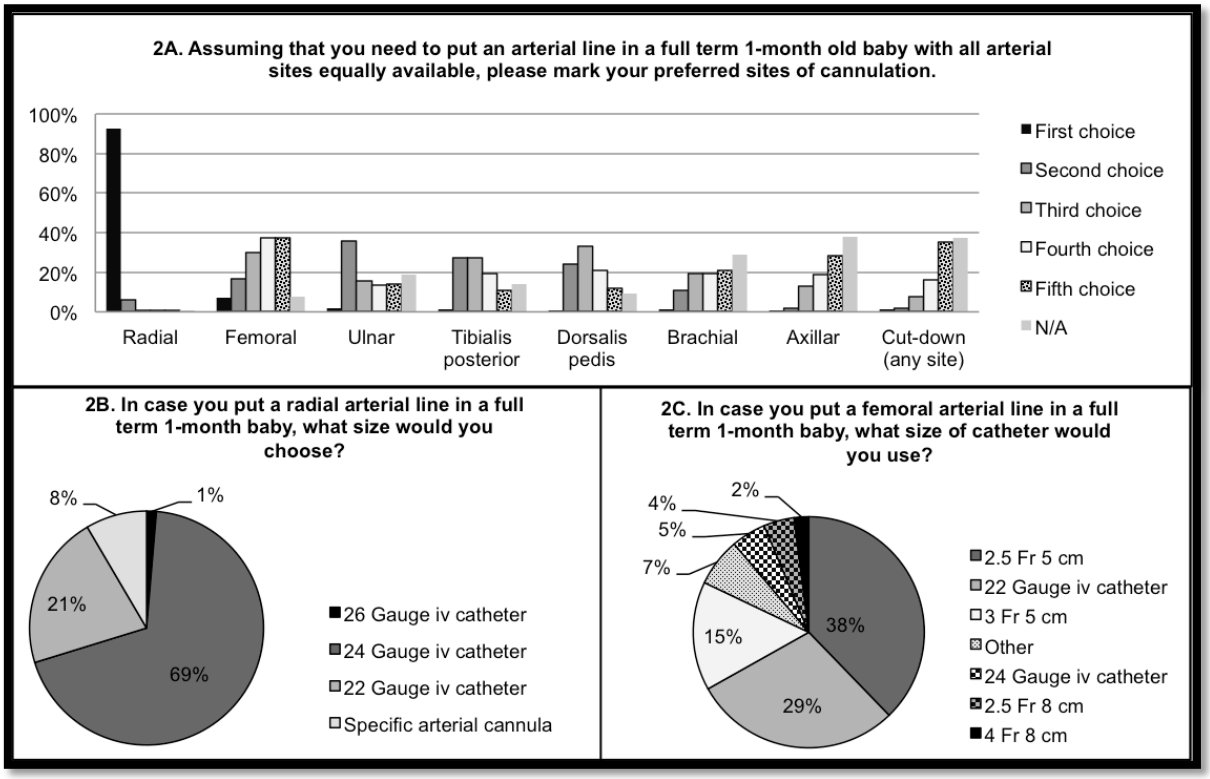


Figure 2. Clinical scenarios. Three questions regarding the cannulation in a full term 1-month old baby were posed. **2A**. Radial artery represents the favourite choice for arterial cannulation in infants, flowed by the femoral artery. Interestingly, ulnar, dorsalis pedis and tibial posterior arteries are chosen more often than axillary and brachial arteries. **2B**. In infants, the radial artery is cannulated with either 24G or 22G intravenous catheter. **2C**. On the other hand, femoral artery is usually cannulated with 2.5Fr 5cm, 22G or 3Fr 5cm catheters.

In the case of failure of catheter insertion at the primary site, 67% of responders declared they would change limb, whereas 20% would not (**Figure 3**).

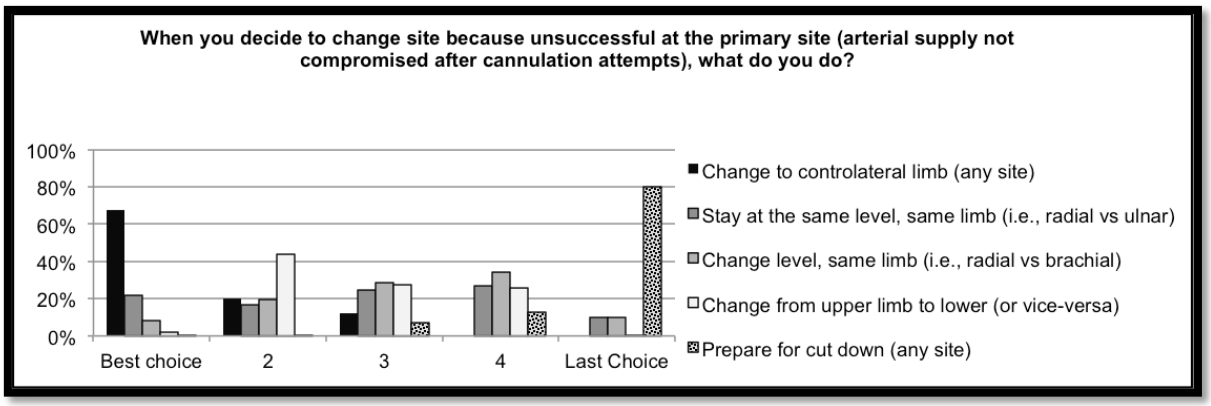


Figure 3. Failure of cannulation the primary site. In case of failure, interviewers prefer to change limb or try another vessel at the same level on the same limb. Access a proximal or distal vessel on the same is uncommon. Cut-down is often considered the last resource.

Insertion technique

The majority of the responders (74%) did not assess collateral perfusion of the hand, comparing those who performed the classical (7%), the modified (9%) or the enhanced (4%) Allen's test (**Figure 4A**).

Anatomical landmarks were the primary method to find the artery (75%), followed by 2D US (19% for real-time insertion and 2% for scan only) and Acoustic Doppler (3%) (**Figure 4B**). In Infants, the techniques for cannulation varied. "Puncturing and threading" the catheter was more often done without the aid of a guidewire in comparison to the guidewire-assisted technique (34% with 12%, respectively). On the contrary, the "going through and draw back" technique was more frequently guidewire assisted than not (34% with 15%, respectively) (**Figure 4C**).

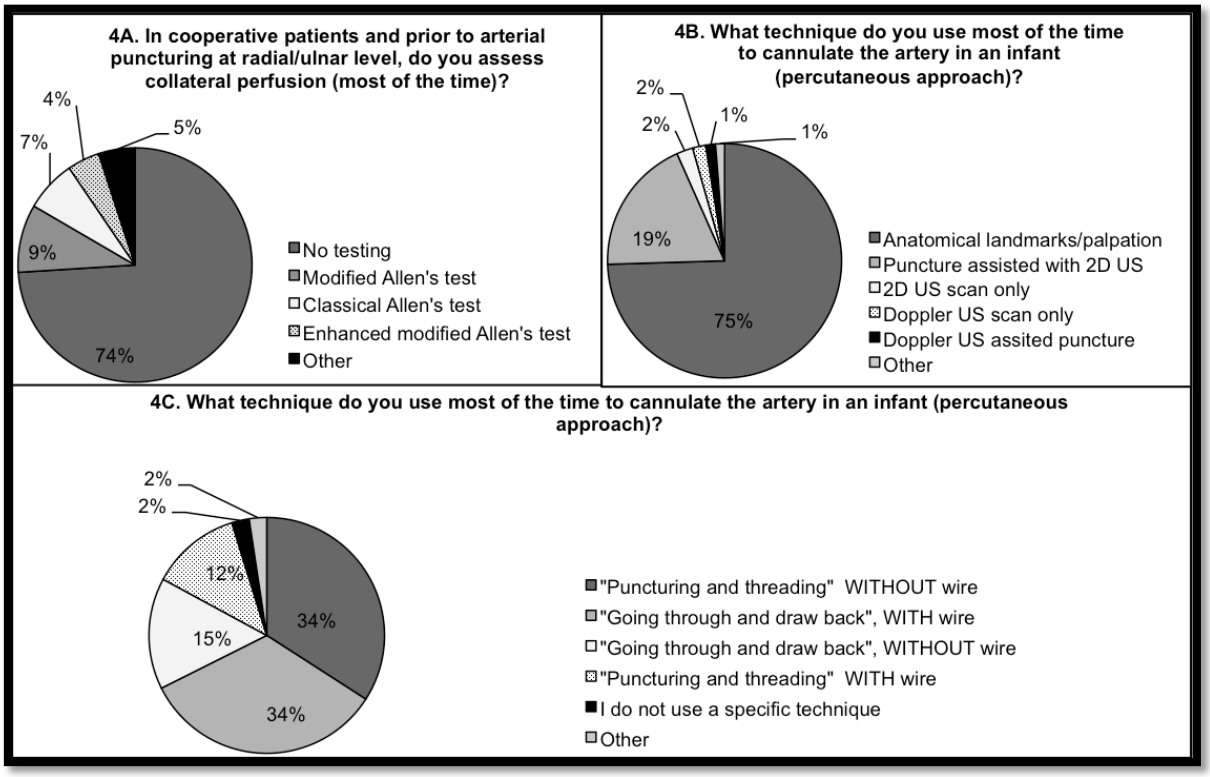


Figure 4. Technical approaches to arterial cannulation. Allen's test is rarely performed to assess collateral circulation (**4A**). In infants, anatomical landmark are preferred over other techniques (**4B**). The "puncturing and threading" (without guidewire) and the guidewire assisted "going through and draw back" techniques are equally chosen (**4C**).

Complications

Overall, complications were reported by 60% of the responders, consisting both in temporary occlusion (42%) and hematoma (33%), followed by thrombosis/embolism (13%), permanent occlusion (4%) and localized infection (2%).

Comparing the rate of declared complications to experience, respondents who put more often arterial line (≥ 25/year) declare less complications (19% vs. 13%, p<001; percentage ± CI 95%, McNemar test p<0.001), concurring with respondents with more than 5 years of practice or who spent more that 3 days/week in a paediatric operating room, who declared also less complications (percentage ± CI 95%, McNemar's test p<0.01) (**Figure 5**).

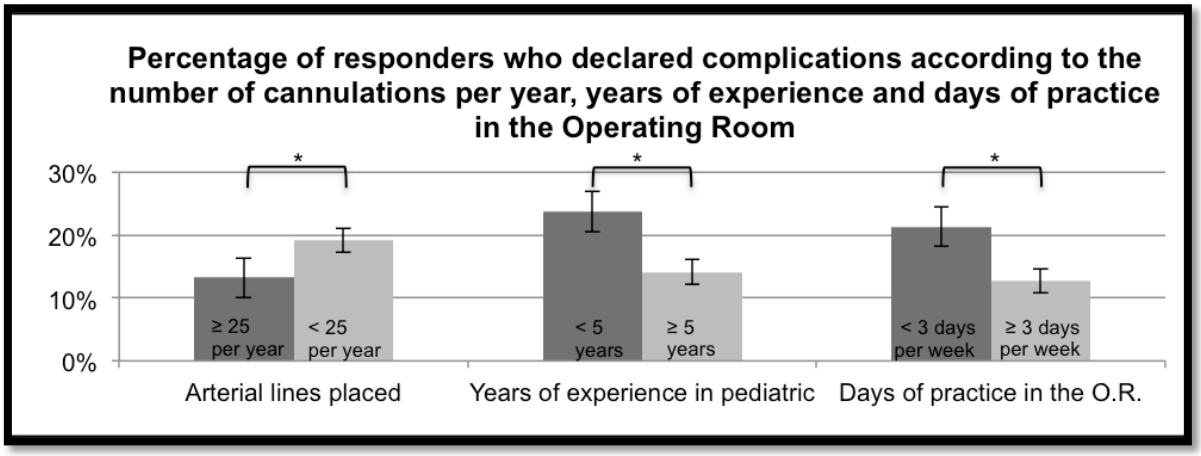


Figure 5. Incidence of complication according to the with respect to the amount of intra-arterial catheter put per year, the years of experience, the amount of days spent in a paediatric operating room.

Utilization of 2D Ultrasound

More than half of the responders (56%) "occasionally" used Acoustic Doppler, and mainly as a rescue technique (41%), or in the case of a non-palpable pulse (36%). One-third (34%) "never" used Acoustic Doppler because they found no advantages (49%) or because they did not have access to it (24%).

Almost two third of the responders (60%) used 2D US "occasionally", as rescue technique or in the case of unidentifiable landmarks. On the other hand, a quarter of the participants used 2D US "most of the time" due to a higher success rate, faster cannulation times or because they considered it a superior technique (Figure 5). Those who "never use" 2D US did not find it advantageous and declared either no experience or no access to it (**Figure 6**).

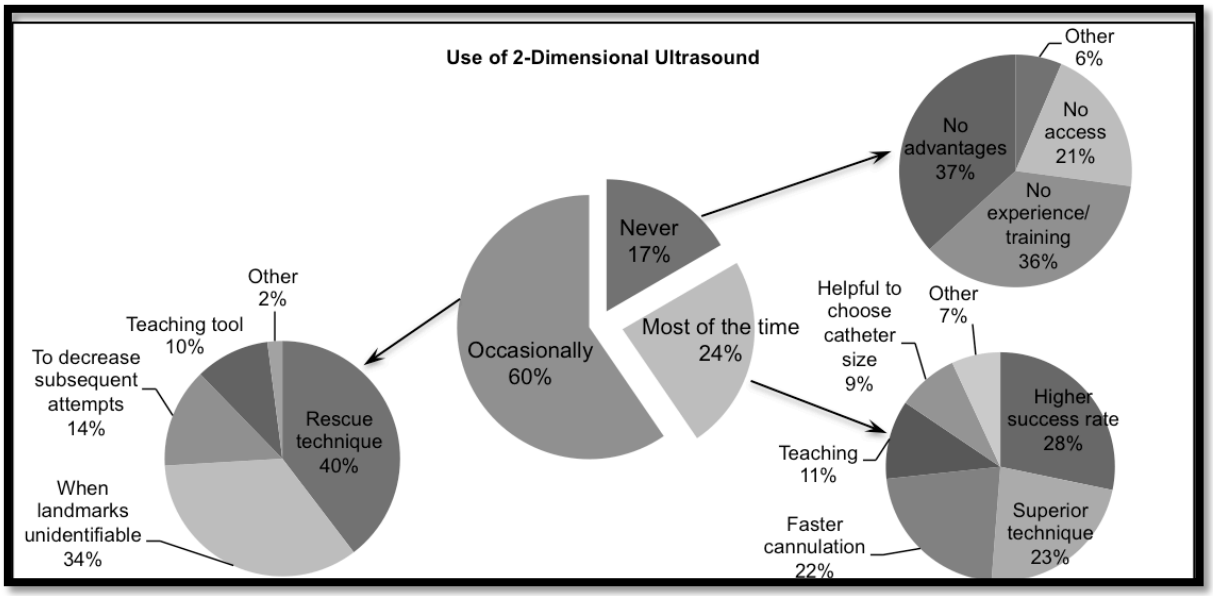


Figure 6. Frequency of utilization of 2 Dimensional Ultrasound and relative reasons.

Anaesthesiologists who worked with children less than 3 days per week in operation room resorted to 2D US more than practitioners who dealt more with children (> 3 days per week)

(**Figure 7A**). On the opposite, those who inserted more than 25 arterial lines per year used 2D US significantly more often than others (p<0.001) (**Figure 7B**).

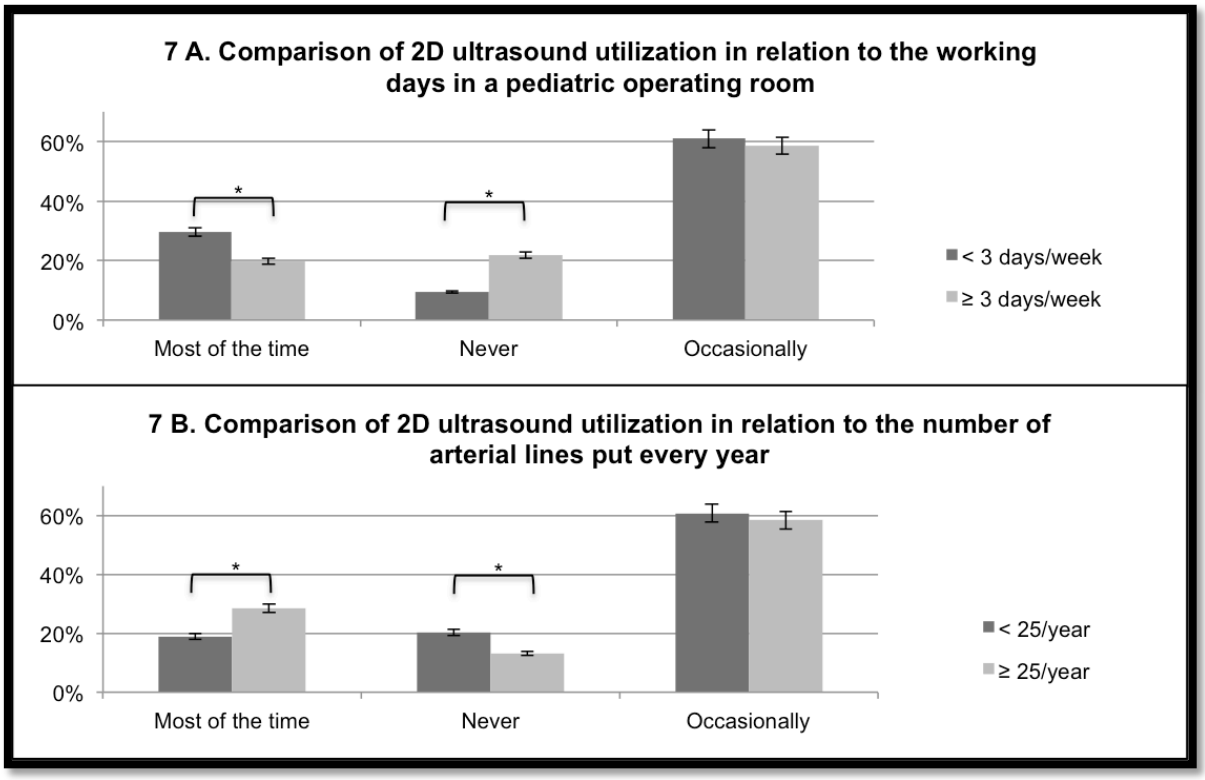


Figure 7. Comparison of 2D US utilization in relation to the working days in a paediatric operating room (**7A**). Use of 2-Dimensional Ultrasound in relation to the frequency of arterial cannulation. Anaesthesiologists who put more than 25 arterial lines per year declare to use the 2-Dimensional Ultrasound more often than the others (percentage ± CI 95%, Kruskal-Wallis p<0.001) (**7B**).

Management of complications and Heparin use for maintenance

The majority of reported complications consisted in temporary occlusion and blanching of the extremity (41,5%), the second most frequent reported complications was hematoma (32,8%) then minor complications and finally permanent occlusion and ischemic damage were only reported in less than 4% of complications (**Figure 8**).

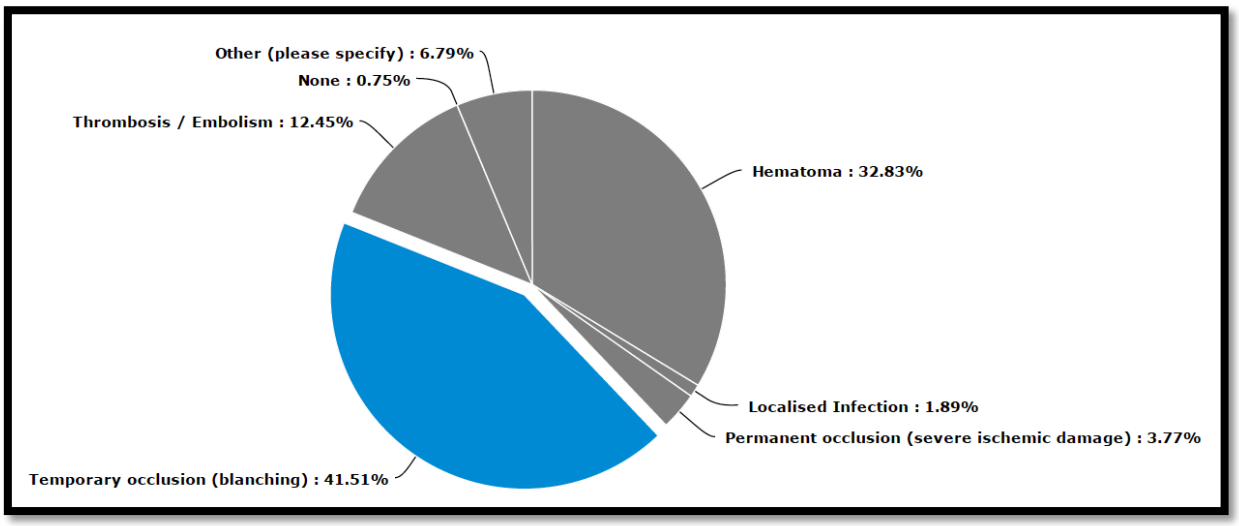


Figure 8. Type and frequency of reported complications.

In the case of blanching of the limb watchful waiting was preferred (41%), followed by warming the extremity (17%), administering lidocaine (15%), removing the cannula (13%), administering papaverine (6%) or administering/increasing the heparin dose (2 and 1%, respectively) (**Figure 9**).

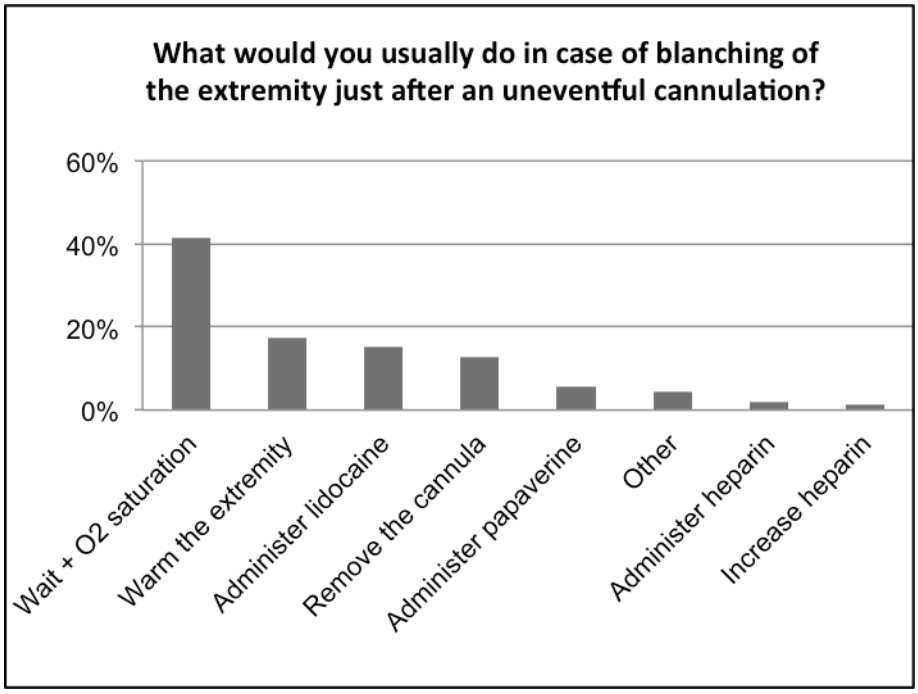


Figure 9. Troubleshooting techniques in case of blanching of the extremity.

The most common regimens for KAO[2] in children < 10kg were normal saline (31%) or saline with heparin 1 IU/ml (41%) (**Figure 10A**) at 0.5, 1 or 2 ml/hr (19%, 47% and 20%, respectively) (**Figure 10B**).

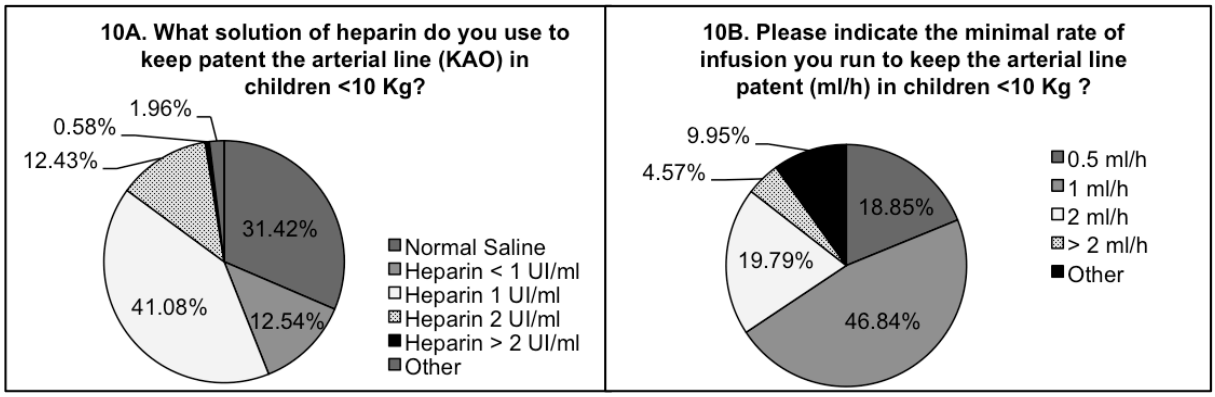


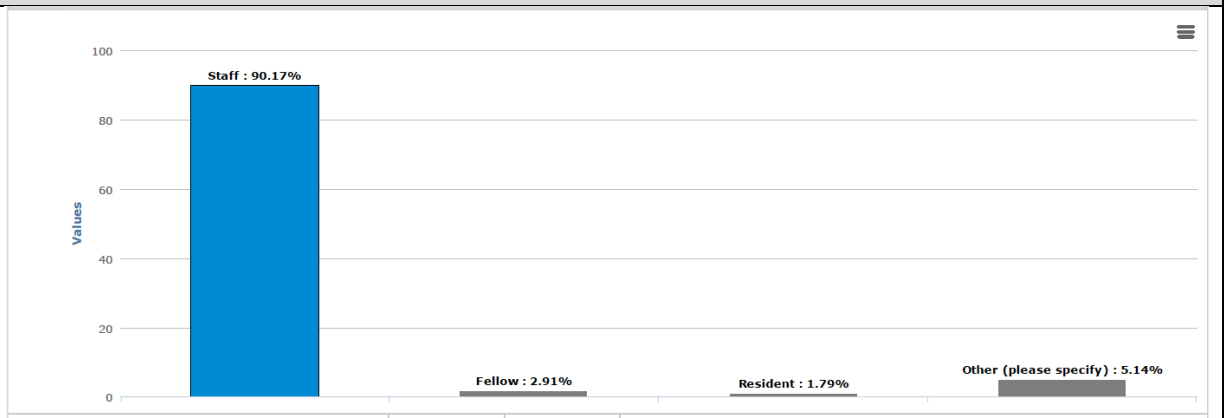
Figure 10. Type of heparin solution reported for children < 10kg **(10A).** Keep Artery Opened regimens reported for children < 10kg (**10B**).

[2] KAO = Keep Artery Opened: minimal infusion rate used as maintenance rate

4.2. Summarized data (only completed questionnaires)

Question 1

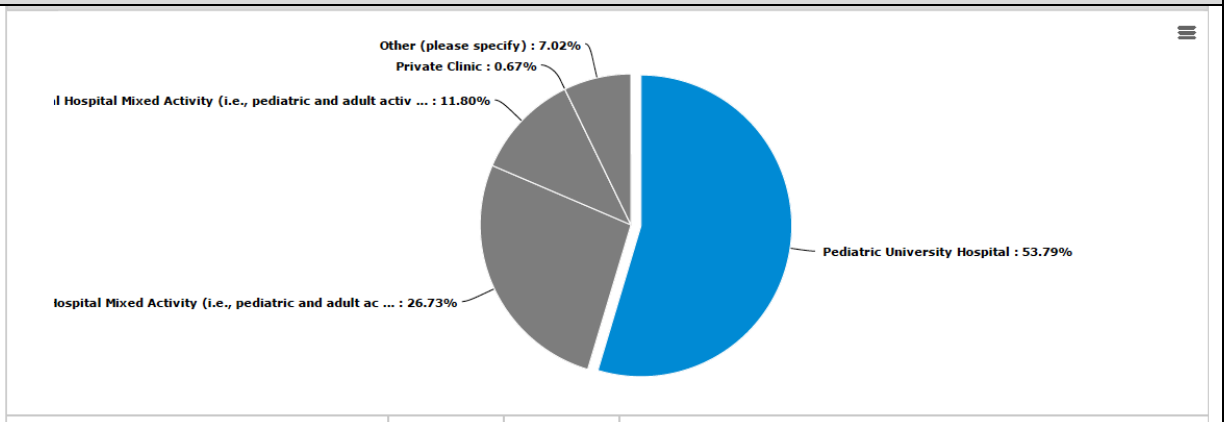
"What is your current position?"



Answer	Count	Percent
1. Staff	807	90.17%
2. Fellow	26	2.91%
3. Resident	16	1.79%
4. Other (please specify)	46	5.14%
Total	895	100%

Question 2

"In what kind of institution do you work most of the time?"



Answer	Count	Percent
1. Pediatric University Hospital	483	53.79%
2. University Hospital Mixed Activity (i.e., pediatric and adult activity)	240	26.73%
3. General Hospital Mixed Activity (i.e., pediatric and adult activity)	106	11.80%
4. Private Clinic	6	0.67%
5. Other (please specify)	63	7.02%
Total	898	100%

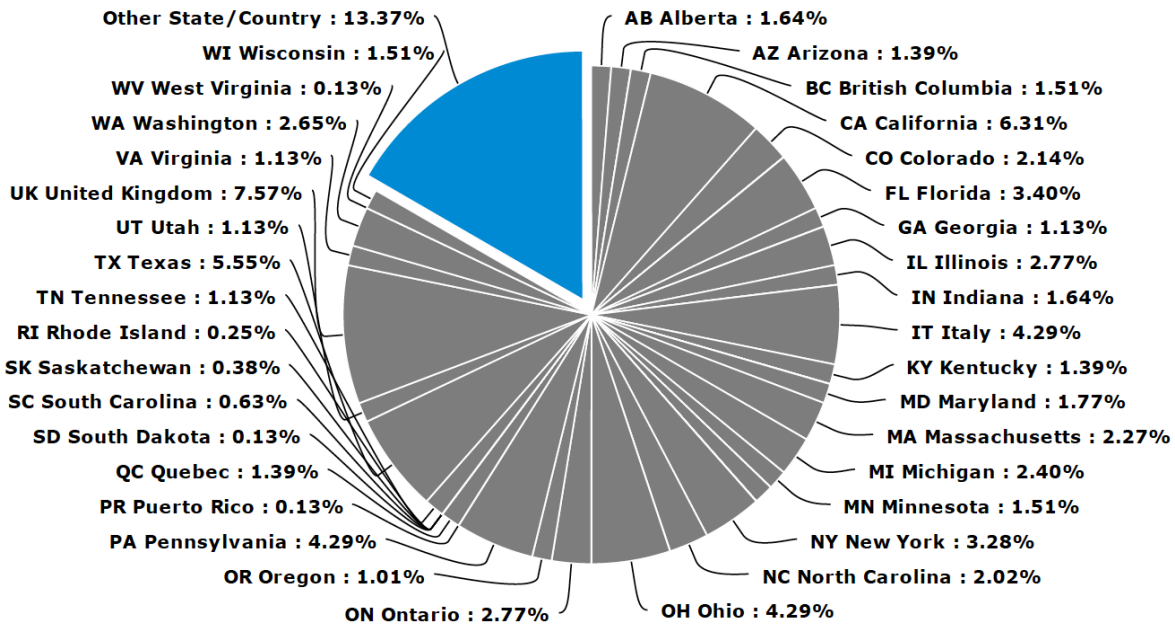
Summarized details and free comments to answer "Other": n = 75

- Paediatric Hospital (non university): n = 61
- Military Hospital mixed activity: n = 2
- Burn Centre: n = 1
- Mixed tertiary orthopaedics: n = 1
- Ambulatory Care Centre mixed activity: n = 3

- Shriners Hospital: n = 3
- Mixed activity (university and general): n = 4

Question 3

"Please provide the Province / State / Country of your medical practice"

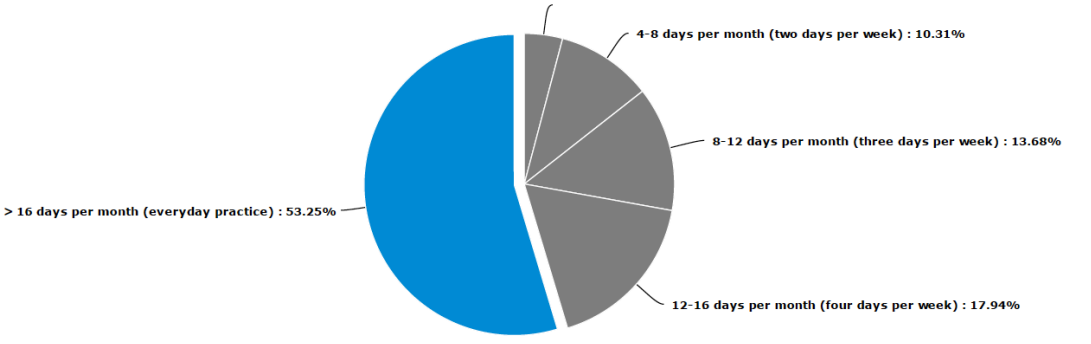


Descriptive data		
UNITED STATES AMERICA	525	66.20%
CANADA	68	8.57%
UNITED KINGDOM	60 (+ 41)	7.57% (12.73%)
ITALY	34 (+ 5)	4.29% (4.91%)
Others (specified below)	106 (- 46)	14.88% (7.56%)
Total	**793**	
Others		
Italy	5	
UK	41	
Irak	1	
Brazil	2	
Netherlands	3	
Poland	1	
Belgium	2	
Australia	5	
Slovakia	1	
Austria	2	
Colombia	2	
Chile	2	
Hungary	1	
Thailand	1	

Switzerland	1	
New Zealand	2	
Japan	1	
Not specified	33	

Question 4

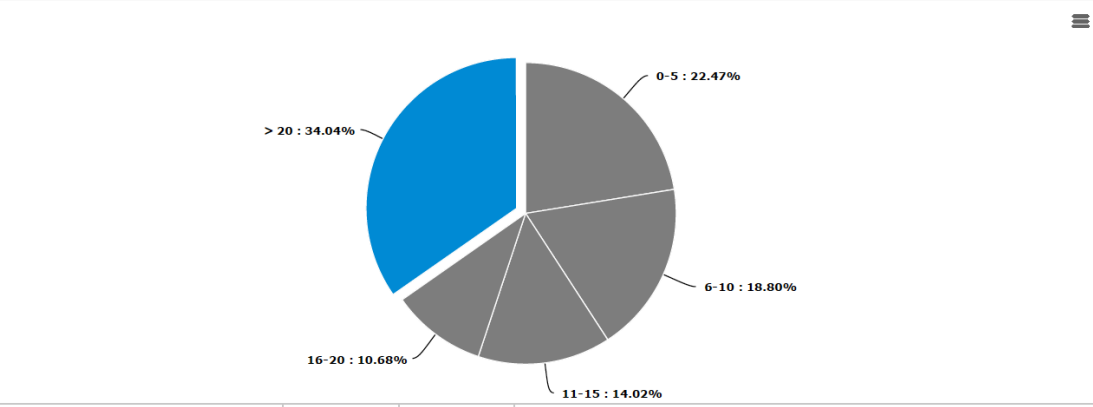
"How often do you practice paediatric anaesthesia in the operating room per month?"



Answer	Count	Percent	20%	40%	60%	80%	100%
1. < 4 days per month (one day per week)	43	4.82%					
2. 4-8 days per month (two days per week)	92	10.31%					
3. 8-12 days per month (three days per week)	122	13.68%					
4. 12-16 days per month (four days per week)	160	17.94%					
5. > 16 days per month (everyday practice)	475	53.25%					
Total	892	100%					

Question 5

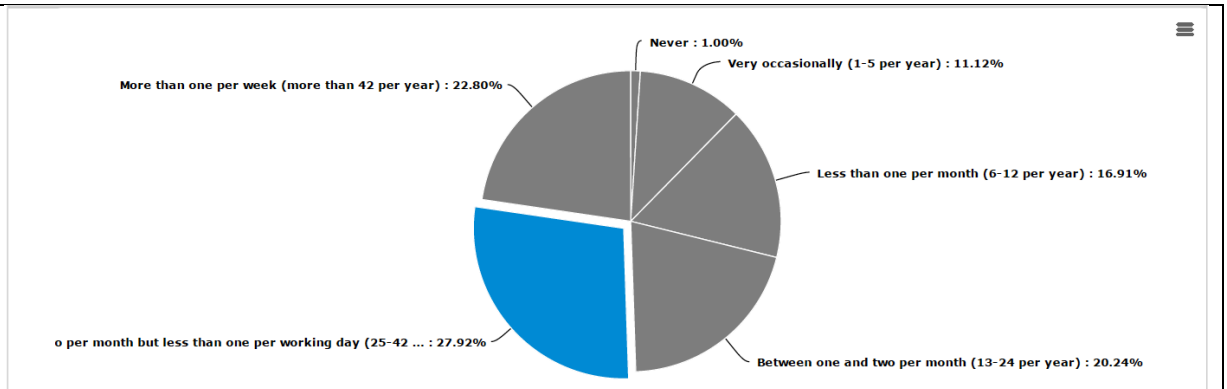
"How many years of experience do you have in paediatric anaesthesia?"



Answer	Count	Percent	20%	40%	60%	80%	100%
1. 0-5	202	22.47%					
2. 6-10	169	18.80%					
3. 11-15	126	14.02%					
4. 16-20	96	10.68%					
5. > 20	306	34.04%					
Total	899	100%					

Question 6

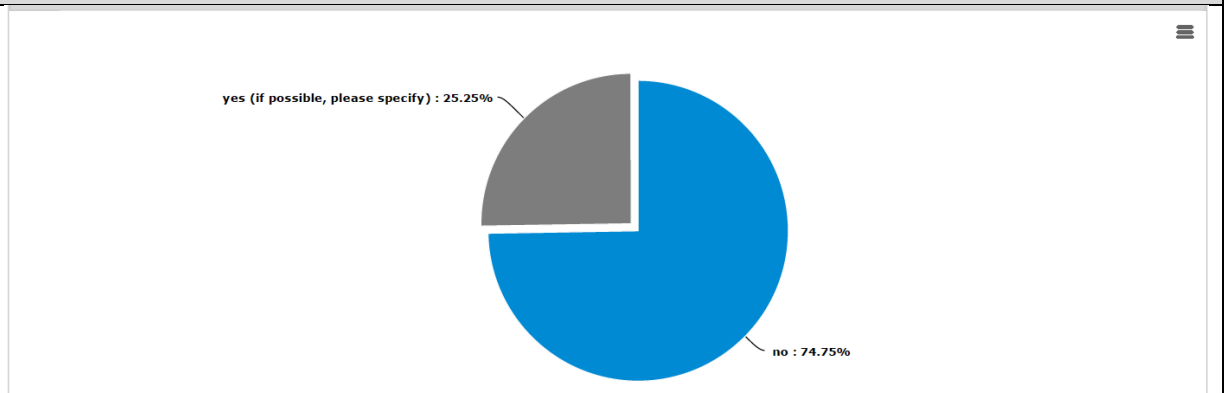
"How often do you place arterial lines in children?"



Answer	Count	Percent	20%	40%	60%	80%	100%
1. Never	9	1.00%					
2. Very occasionally (1-5 per year)	100	11.12%					
3. Less than one per month (6-12 per year)	152	16.91%					
4. Between one and two per month (13-24 per year)	182	20.24%					
5. **More than two per month but less than one per working day (25-42 per year)**	251	27.92%					
6. More than one per week (more than 42 per year)	205	22.80%					
Total	899	100%					

Question 7

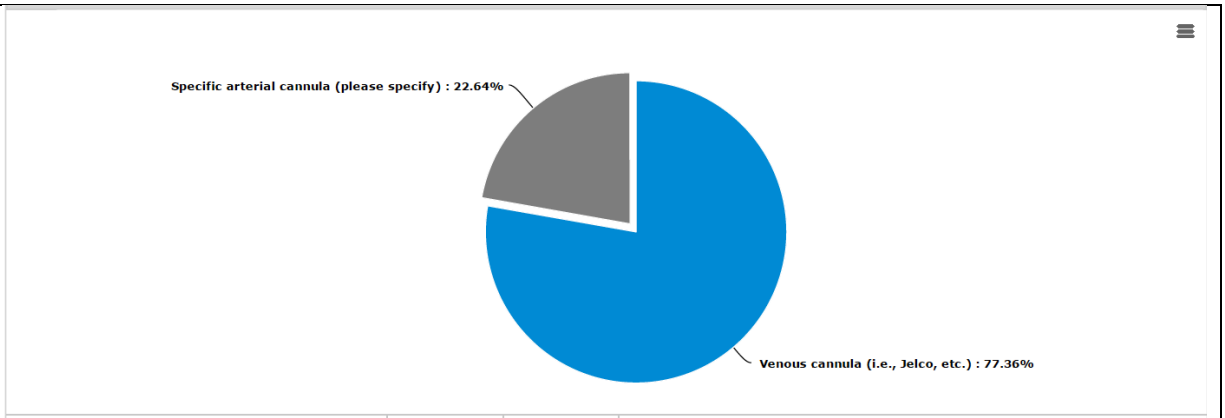
”Do you have local written guidelines for arterial cannulation (i.e. technique, dressing, sterile precaution)?”



Answer	Count	Percent	20%	40%	60%	80%	100%
1. no	663	74.75%					
2. yes (if possible, please specify)	224	25.25%					
Total	887	100%					

Question 8

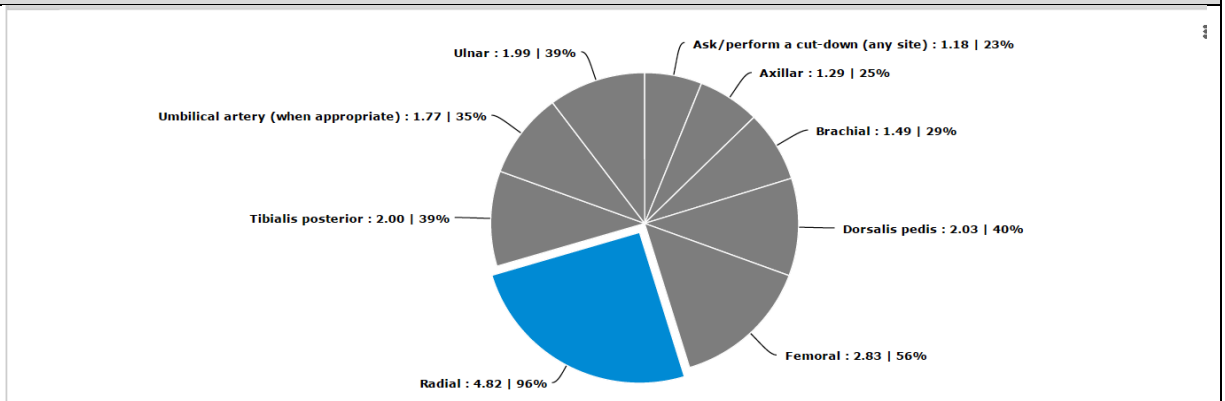
“What medical device do you usually prefer for arterial cannulation in paediatric patients?”



Answer	Count	Percent	20% 40% 60% 80% 100%
1. Venous cannula (i.e., Jelco, etc.)	687	77.36%	
2. Specific arterial cannula (please specify)	201	22.64%	
Total	888	100%	

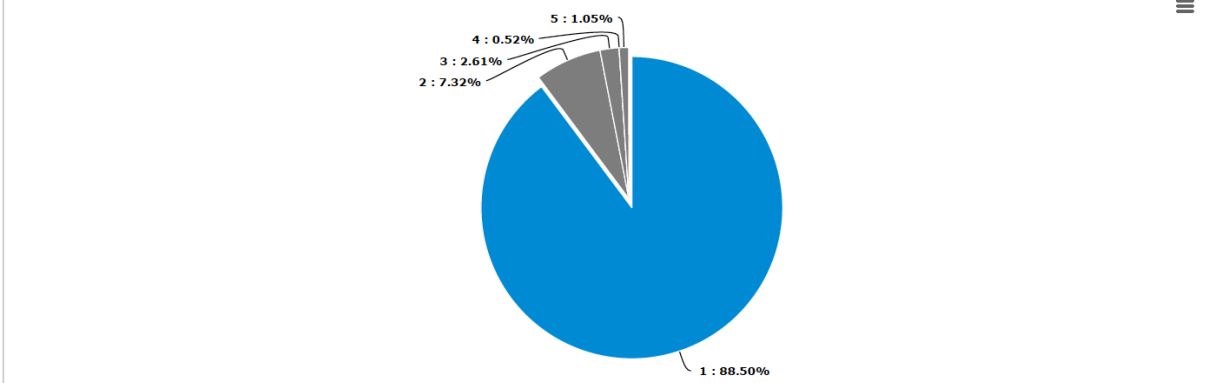
Question 9

"How often do you use the following sites as first choice for arterial cannulation? (5 stars = most of the time; 1 star = least of the time)"



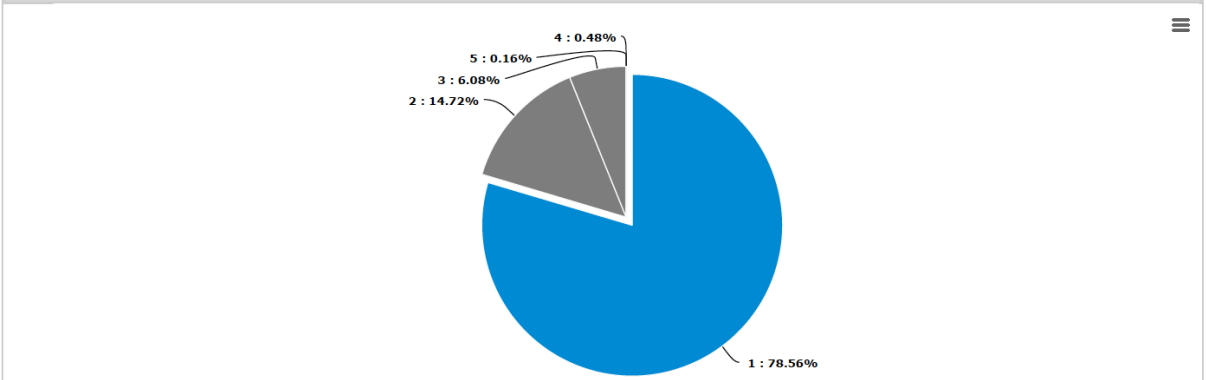
Question	Count	Score	1 2 3 4
1. Ask/perform a cut-down (any site)	574	1.18	
2. Axillar	625	1.29	
3. Brachial	653	1.49	
4. Dorsalis pedis	703	2.03	
5. Femoral	775	2.83	
6. Radial	**885**	**4.82**	
7. Tibialis posterior	668	2.00	
8. Umbilical artery (when appropriate)	605	1.77	
9. Ulnar	681	1.99	

1. Ask/perform a cut-down (any site)



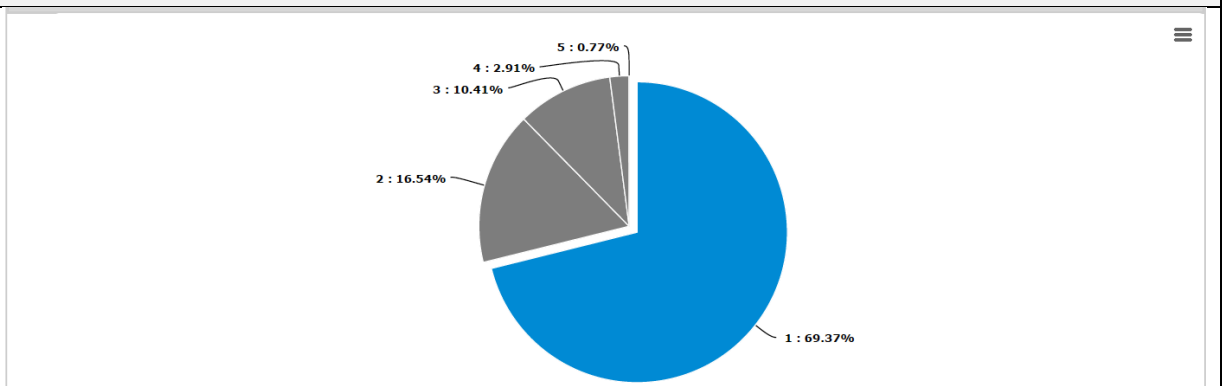
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	508	88.50%					
2. 2	42	7.32%					
3. 3	15	2.61%					
4. 4	3	0.52%					
5. 5	6	1.05%					
Total	574	100%					

2. Axillar site



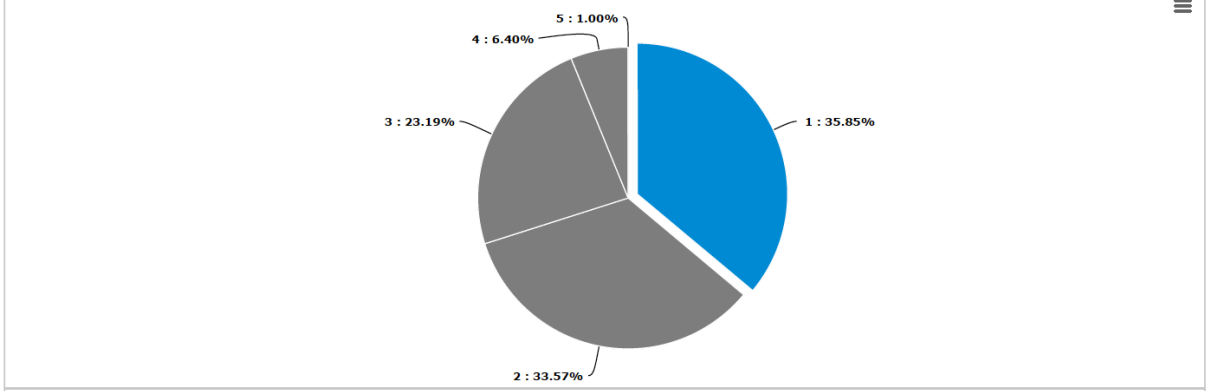
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	491	78.56%					
2. 2	92	14.72%					
3. 3	38	6.08%					
4. 4	3	0.48%					
5. 5	1	0.16%					
Total	625	100%					

3. Brachial site



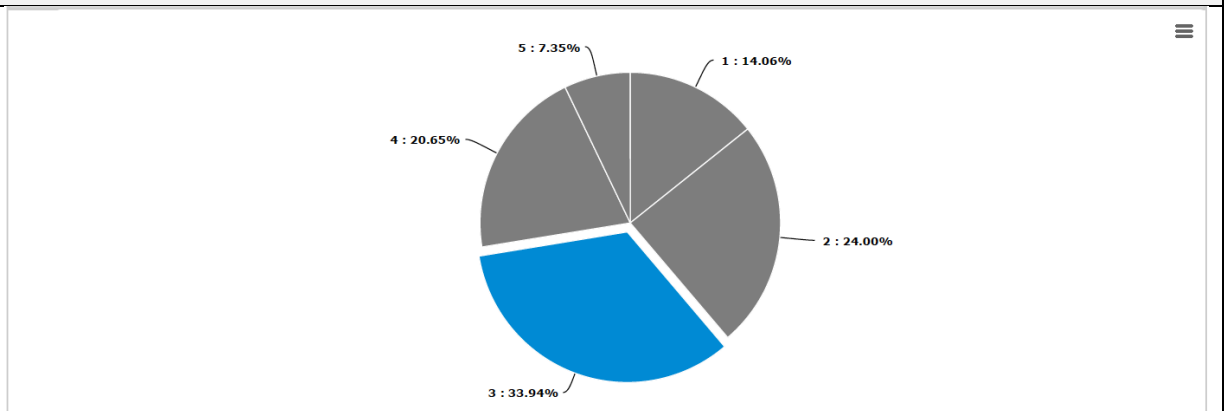
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	453	69.37%					
2. 2	108	16.54%					
3. 3	68	10.41%					
4. 4	19	2.91%					
5. 5	5	0.77%					
Total	653	100%					

4. Dorsalis pedis site



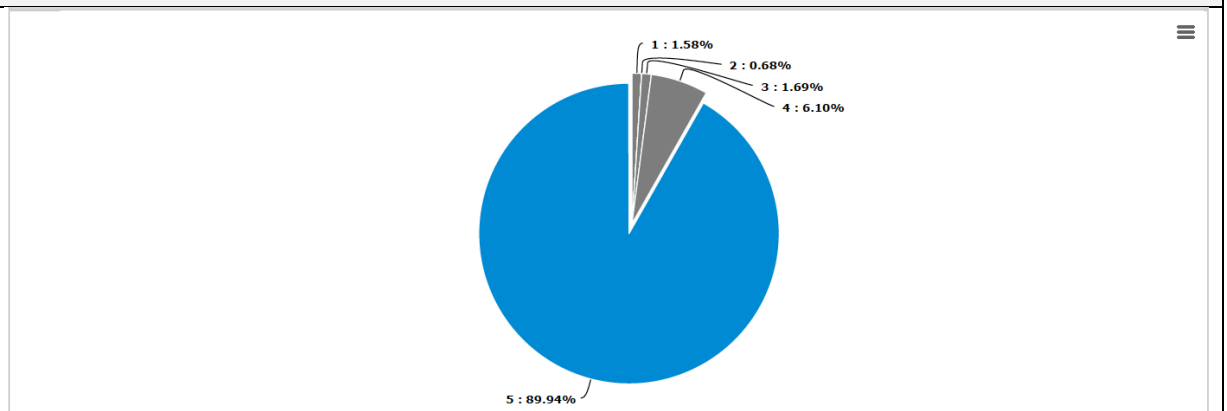
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	252	35.85%					
2. 2	236	33.57%					
3. 3	163	23.19%					
4. 4	45	6.40%					
5. 5	7	1.00%					
Total	703	100%					

5. Femoral site



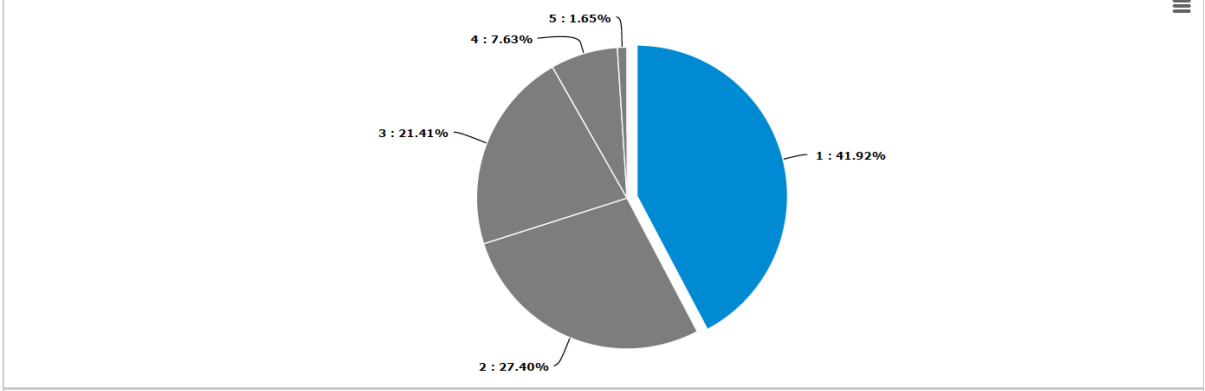
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	109	14.06%					
2. 2	186	24.00%					
3. 3	263	33.94%					
4. 4	160	20.65%					
5. 5	57	7.35%					
Total	775	100%					

6. Radial site



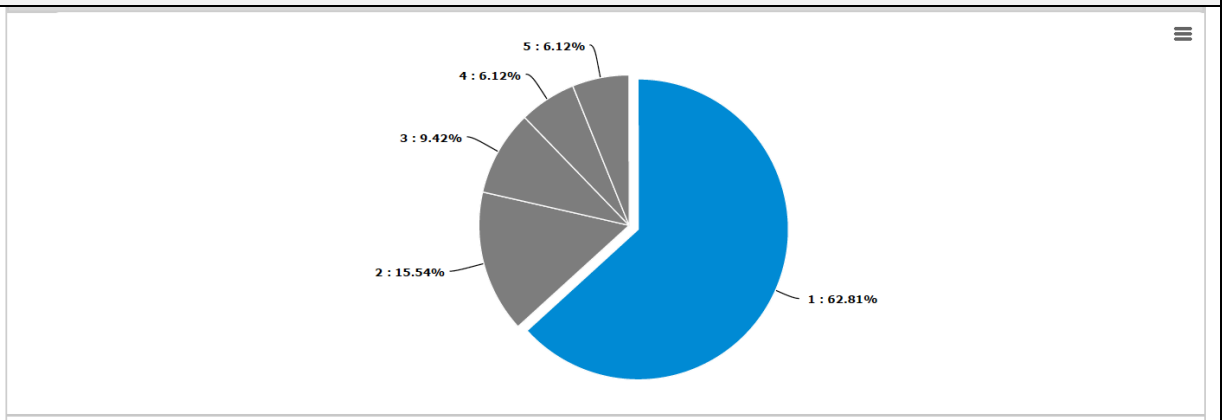
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	14	1.58%					
2. 2	6	0.68%					
3. 3	15	1.69%					
4. 4	54	6.10%					
5. 5	796	89.94%					
Total	885	100%					

7. Tibialis posterior site



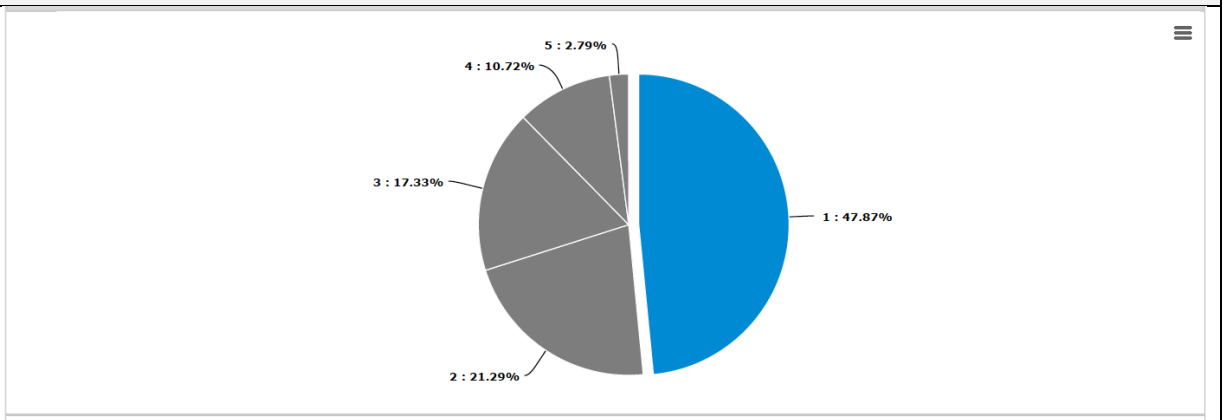
Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	280	41.92%					
2. 2	183	27.40%					
3. 3	143	21.41%					
4. 4	51	7.63%					
5. 5	11	1.65%					
Total	668	100%					

8. Umbilical artery site (when appropriate)



Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	380	62.81%					
2. 2	94	15.54%					
3. 3	57	9.42%					
4. 4	37	6.12%					
5. 5	37	6.12%					
Total	605	100%					

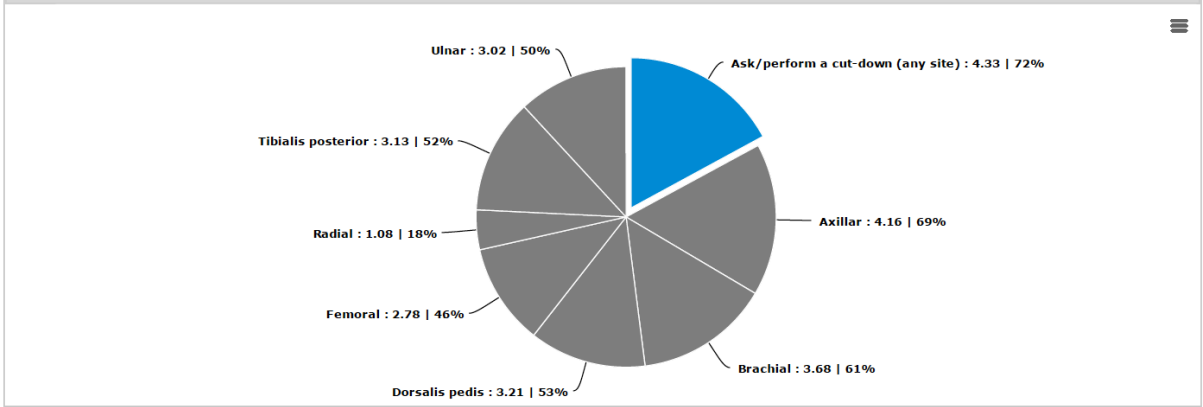
9. Ulnar site



Answer	Count	Percent	20%	40%	60%	80%	100%
1. 1	326	47.87%					
2. 2	145	21.29%					
3. 3	118	17.33%					
4. 4	73	10.72%					
5. 5	19	2.79%					
Total	681	100%					

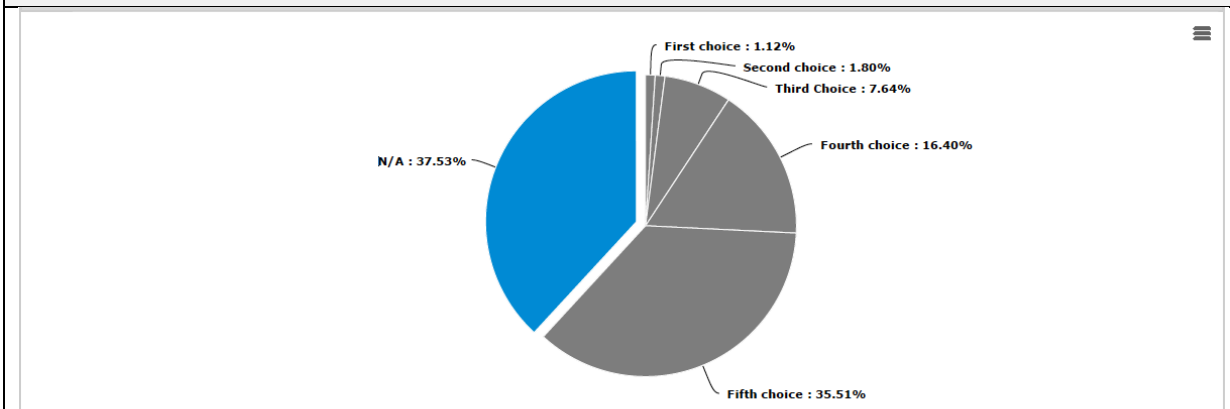
Question 10 (“baby scenario 1”)

“Assuming that you need to put an arterial line in a full term 1 month old baby with all arterial sites equally available (no specific concerns related to surgery or patient’s disease), please mark your preferred sites of cannulation (up to five)?”



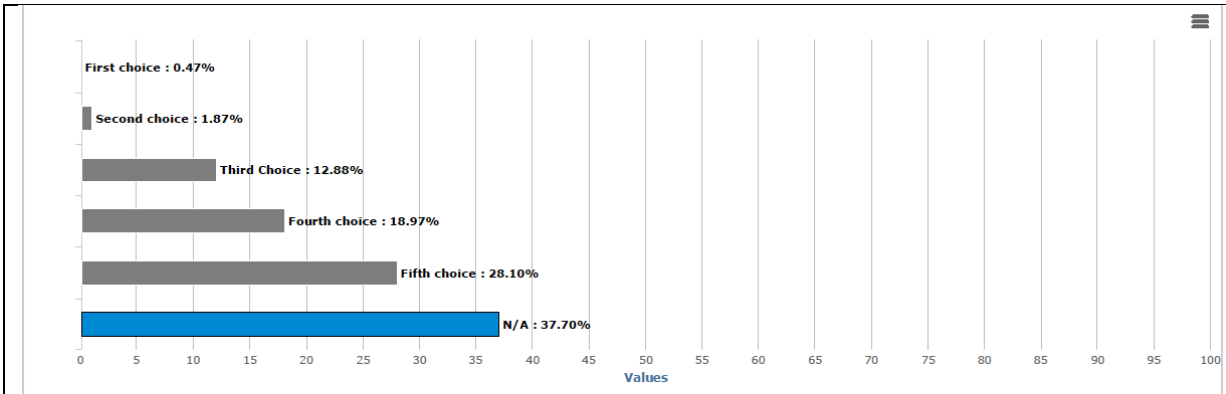
Question	Count	Score	First choice	Second choice	Third Choice	Fourth choice	Fifth choice	N/A
1. Ask/perform a cut-down (any site)	445	4.33						
2. Axillar	427	4.16						
3. Brachial	461	3.68						
4. Dorsalis pedis	550	3.21						
5. Femoral	795	2.78						
6. Radial	874	1.08						
7. Tibialis posterior	555	3.13						
8. Ulnar	525	3.02						

1. Ask/perform a cut-down (any site)



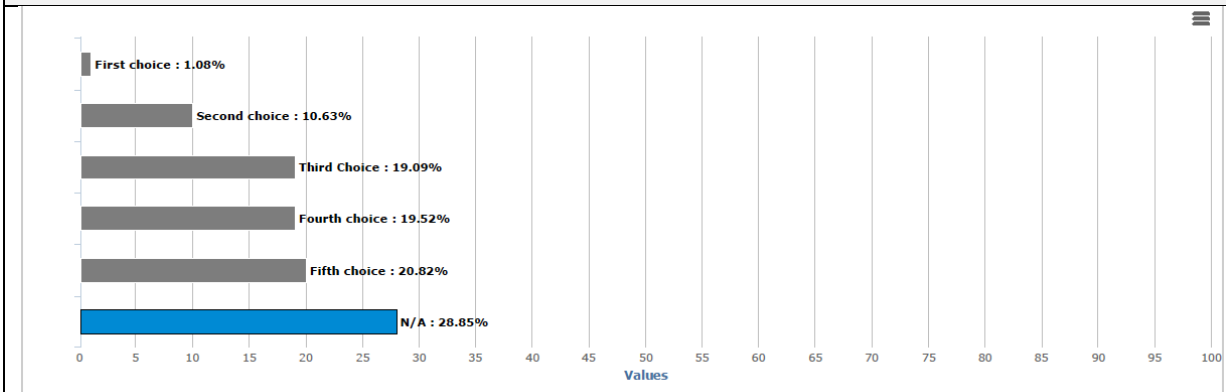
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	5	1.12%					
2. Second choice	8	1.80%					
3. Third Choice	34	7.64%					
4. Fourth choice	73	16.40%					
5. Fifth choice	158	35.51%					
6. N/A	167	37.53%					
Total	445	100%					

2. Axillar site



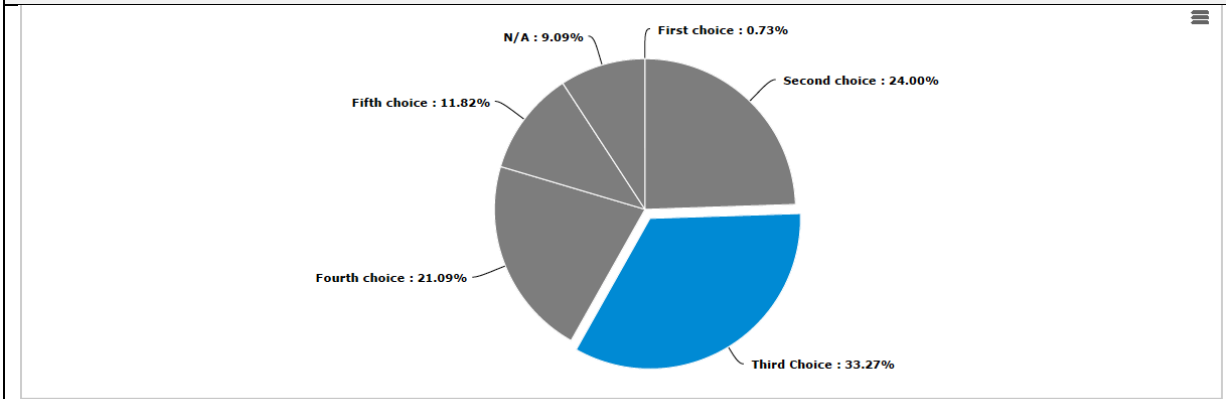
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	2	0.47%					
2. Second choice	8	1.87%					
3. Third Choice	55	12.88%					
4. Fourth choice	81	18.97%					
5. Fifth choice	120	28.10%					
6. N/A	**161**	**37.70%**					
Total	427	100%					

3. Brachial site



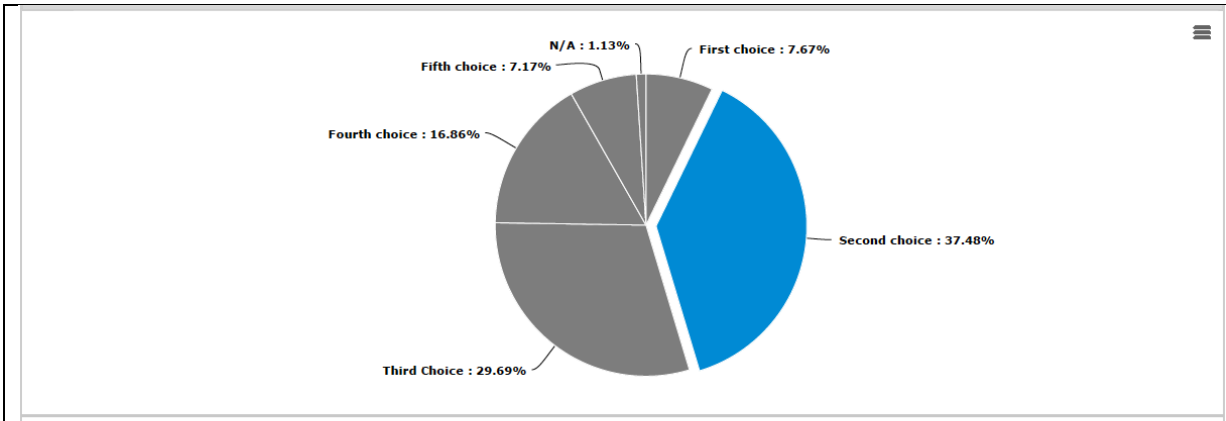
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	5	1.08%					
2. Second choice	49	10.63%					
3. Third Choice	88	19.09%					
4. Fourth choice	90	19.52%					
5. Fifth choice	96	20.82%					
6. N/A	**133**	**28.85%**					
Total	461	100%					

4. Dorsalis pedis site



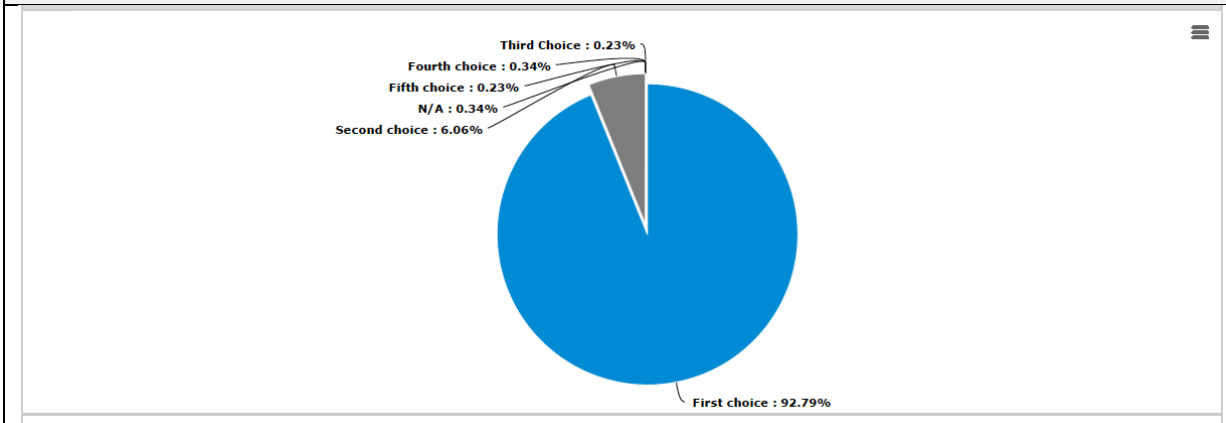
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	4	0.73%					
2. Second choice	132	24.00%					
3. Third Choice	**183**	**33.27%**					
4. Fourth choice	116	21.09%					
5. Fifth choice	65	11.82%					
6. N/A	50	9.09%					
Total	550	100%					

5. Femoral site



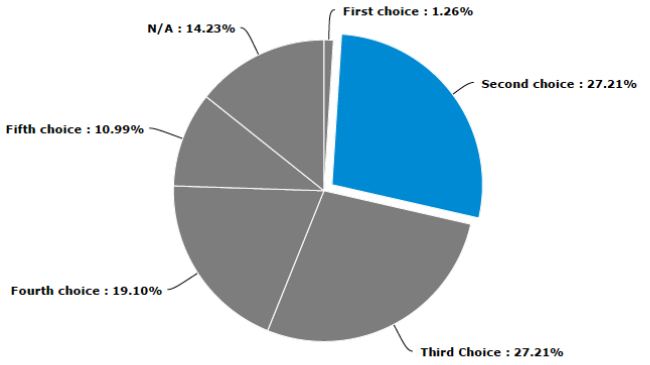
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	61	7.67%					
2. Second choice	**298**	**37.48%**					
3. Third Choice	236	29.69%					
4. Fourth choice	134	16.86%					
5. Fifth choice	57	7.17%					
6. N/A	9	1.13%					
Total	**795**	**100%**					

6. Radial site



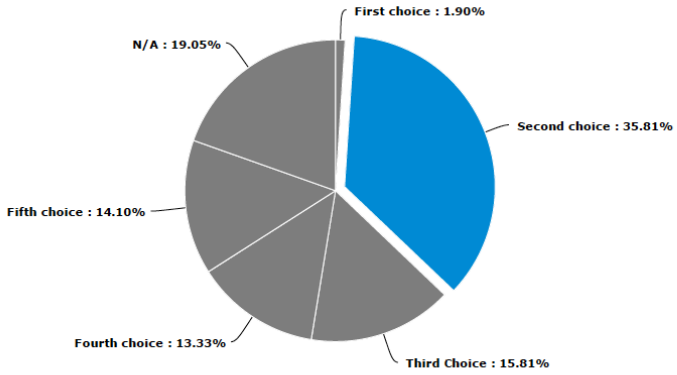
Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	**811**	**92.79%**					
2. Second choice	53	6.06%					
3. Third Choice	2	0.23%					
4. Fourth choice	3	0.34%					
5. Fifth choice	2	0.23%					
6. N/A	3	0.34%					
Total	**874**	**100%**					

7. Tibialis posterior site



Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	7	1.26%					
2. Second choice	**151**	**27.21%**					
3. Third Choice	151	27.21%					
4. Fourth choice	106	19.10%					
5. Fifth choice	61	10.99%					
6. N/A	79	14.23%					
Total	**555**	**100%**					

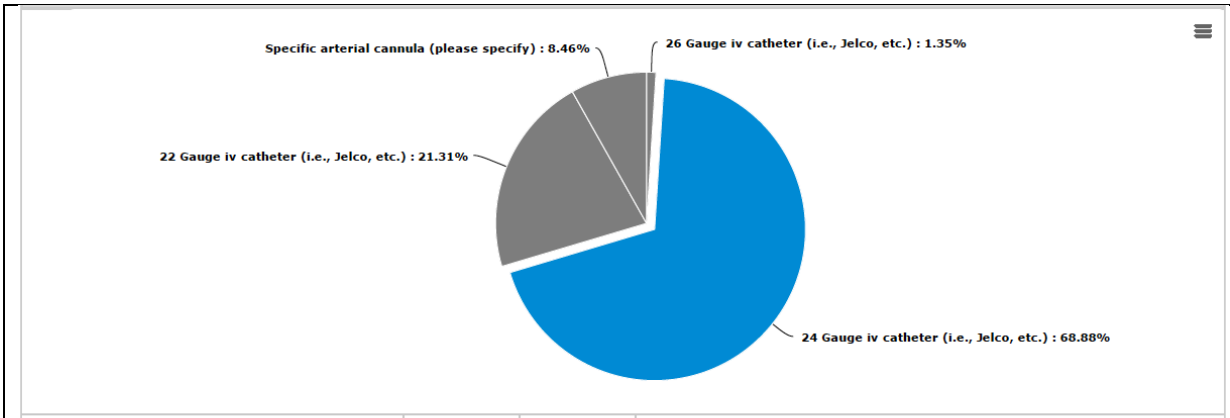
8. Ulnar site



Answer	Count	Percent	20%	40%	60%	80%	100%
1. First choice	10	1.90%					
2. Second choice	**188**	**35.81%**					
3. Third Choice	83	15.81%					
4. Fourth choice	70	13.33%					
5. Fifth choice	74	14.10%					
6. N/A	100	19.05%					
Total	**525**	**100%**					

Question 11 ("baby scenario 2")

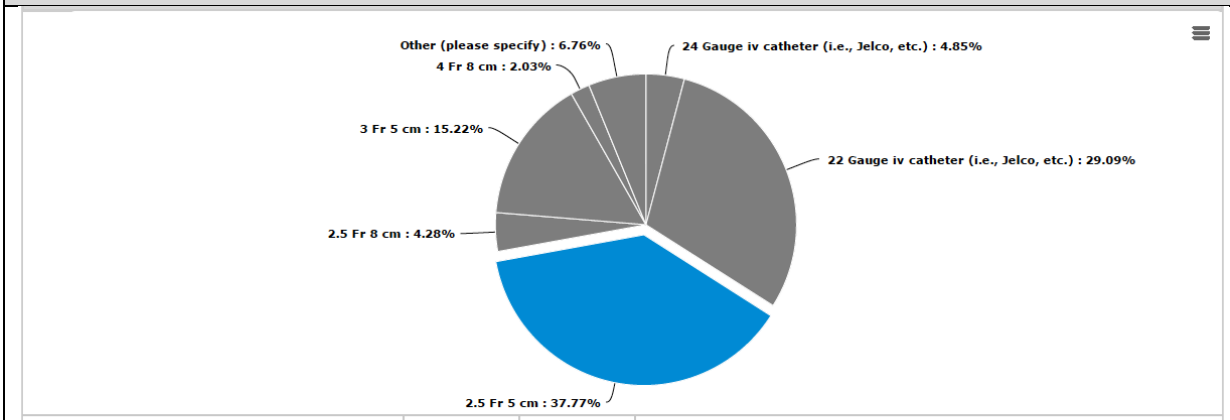
"In case you put a radial arterial line in a full term 1 month old baby, what size would you choose?"



Answer	Count	Percent
1. 26 Gauge iv catheter (i.e., Jelco, etc.)	12	1.35%
2. 24 Gauge iv catheter (i.e., Jelco, etc.)	**611**	**68.88%**
3. 22 Gauge iv catheter (i.e., Jelco, etc.)	189	21.31%
4. Specific arterial cannula (please specify)	75	8.46%
Total	**887**	**100%**

Question 12 ("baby scenario 3")

"In case you put a femoral arterial line in a full term 1 month old baby, what size of catheter would you use?"



Answer	Count	Percent
1. 24 Gauge iv catheter (i.e., Jelco, etc.)	43	4.85%
2. 22 Gauge iv catheter (i.e., Jelco, etc.)	258	29.09%
3. 2.5 Fr 5 cm	**335**	**37.77%**
4. 2.5 Fr 8 cm	38	4.28%
5. 3 Fr 5 cm	135	15.22%
6. 4 Fr 8 cm	18	2.03%
7. Other (please specify)	60	6.76%
Total	**887**	**100%**

Question 13

"When you decide to change site because unsuccessful at the primary site (arterial supply not compromised after cannulation attempts), what would you do?"

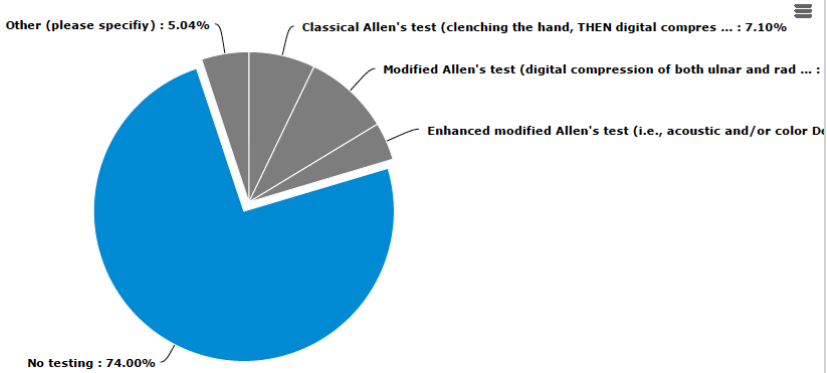
	Average Rank		1	2	3	4	5
1.	Staying at the same level, same limb (i.e., radial vs ulnar or posterior tibial vs dorsalis pedis)	2.86					
2.	Changing level, same limb (i.e., radial vs brachial or axillar)	3.17					
3.	Changing to controlateral limb (any site)	1.46					
4.	Changin from upper limb to lower (or vice-versa)	2.79					
5.	Prepare for cut down (any site)	4.72					

Data Table

1.	Staying at the same level, same limb (i.e., radial vs ulnar or posterior tibial vs dorsalis pedis)	186	21.73%	144	16.82%	211	24.65%	230	26.87%	85	9.93%
2.	Changing level, same limb (i.e., radial vs brachial or axillar)	72	8.41%	166	19.39%	244	28.50%	291	34.00%	83	9.70%
3.	**Changing to controlateral limb (any site)**	**577**	**67.41%**	**170**	**19.86%**	**104**	**12.15%**	**5**	**0.58%**	**0**	**0.00%**
4.	Changin from upper limb to lower (or vice-versa)	18	2.10%	375	43.81%	237	27.69%	222	25.93%	4	0.47%
5.	Prepare for cut down (any site)	3	0.35%	1	0.12%	60	7.01%	108	12.62%	684	79.91%

Question 14

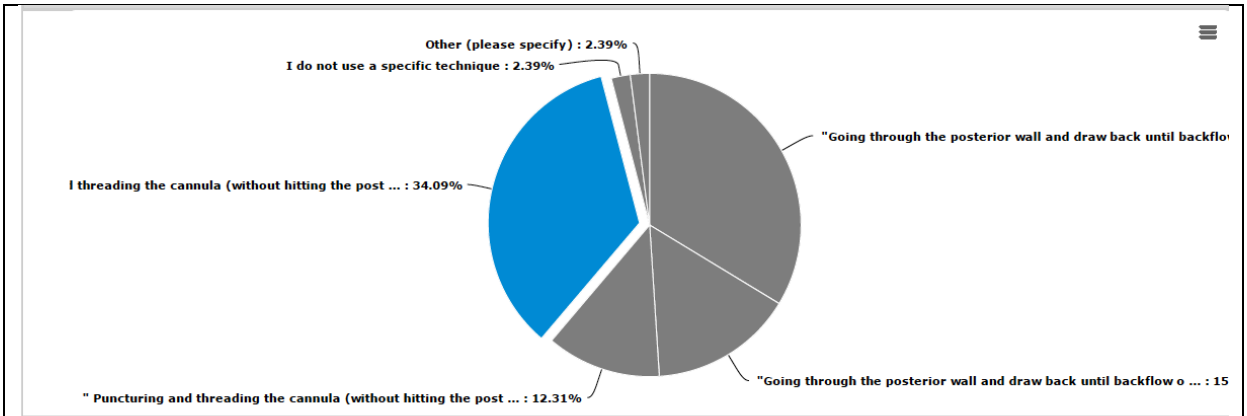
"In cooperative patients and prior to arterial puncturing at radial/ulnar level, do you assess the collateral perfusion (most of the time)?"



	Answer	Count	Percent	20%	40%	60%	80%	100%
1.	Classical Allen's test (clenching the hand, THEN digital compression of both ulnar and radial arteries, THEN opening the hand and release the pressure on ulnar artery, measure the reperfusion time)	62	7.10%					
2.	Modified Allen's test (digital compression of both ulnar and radial arteries, THEN clenching and opening the hand, THEN release the pressure on ulnar artery followed by the radial artery, measure the reperfusion time)	82	9.39%					
3.	Enhanced modified Allen's test (i.e., acoustic and/or color Doppler to evaluate reperfusion adequacy, plethysmography, saturometer during classic Allen's test)	39	4.47%					
4.	**No testing**	**646**	**74.00%**					
5.	Other (please specifiy)	44	5.04%					
	Total	**873**	**100%**					

Question 15

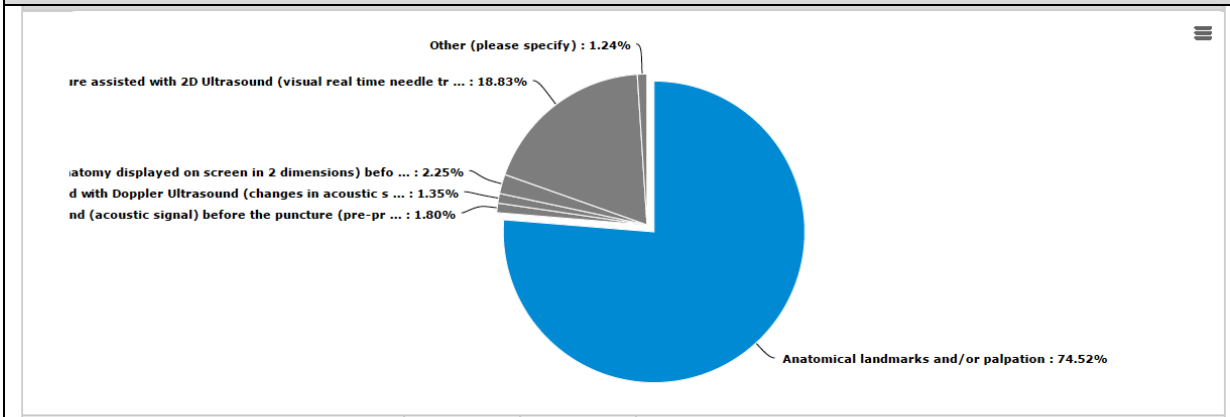
"What technique do you use most of the time to cannulate the artery in an infant (percutaneous approach)?"



	Answer	Count	Percent
1.	"Going through the posterior wall and draw back until backflow of blood is seen", then thread OVER a wire (Seldinger technique)	294	33.52%
2.	"Going through the posterior wall and draw back until backflow of blood is seen", then thread WITHOUT a wire	134	15.28%
3.	" Puncturing and threading the cannula (without hitting the posterior wall)" OVER a wire (Seldinger technique)	108	12.31%
4.	**" Puncturing and threading the cannula (without hitting the posterior wall)" WITHOUT a wire**	299	34.09%
5.	I do not use a specific technique	21	2.39%
6.	Other (please specify)	21	2.39%
	Total	**877**	**100%**

Question 16

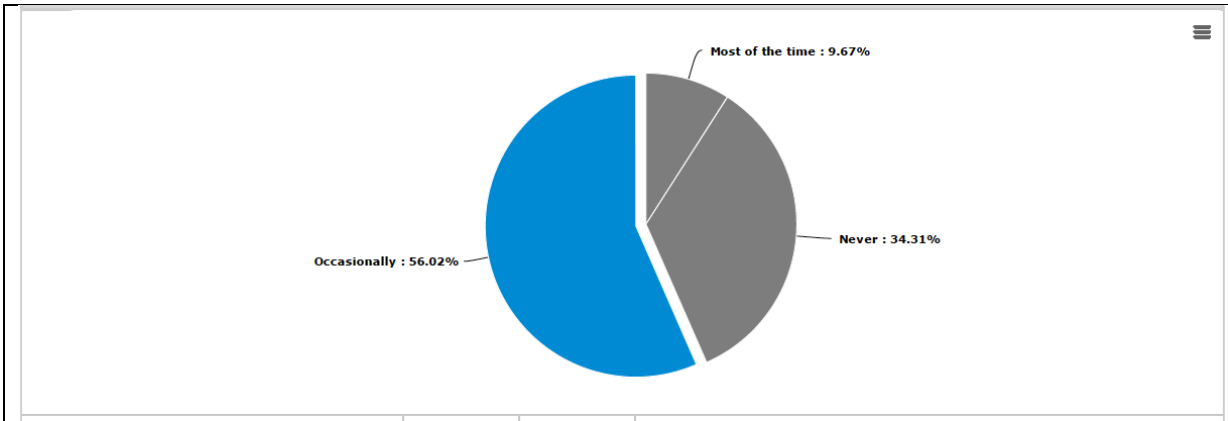
"To locate the artery, what technique do you use most of the time?" **



	Answer	Count	Percent
1.	**Anatomical landmarks and/or palpation**	661	74.52%
2.	Doppler Ultrasound (acoustic signal) before the puncture (pre-procedural scan only)	16	1.80%
3.	Puncture assisted with Doppler Ultrasound (changes in acoustic signal during arterial puncturing; real time scan)	12	1.35%
4.	2D Ultrasound (anatomy displayed on screen in 2 dimensions) before the puncture (pre-procedural scan only)	20	2.25%
5.	Puncture assisted with 2D Ultrasound (visual real time needle tracking, in plane or out of plane)	167	18.83%
6.	Other (please specify)	11	1.24%
	Total	**887**	**100%**

Question 17

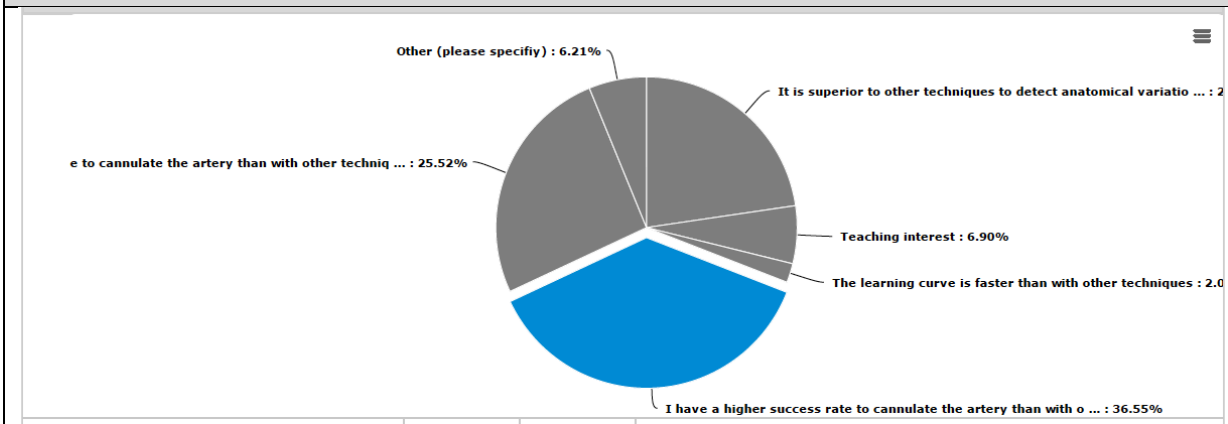
"How often do you use Doppler Ultrasound (acoustic signal) to assist arterial line placement?"



Answer	Count	Percent
1. Most of the time	86	9.67%
2. Never	305	34.31%
3. Occasionally	498	56.02%

Question 18 (branching Q17 – answer "Most of the time")

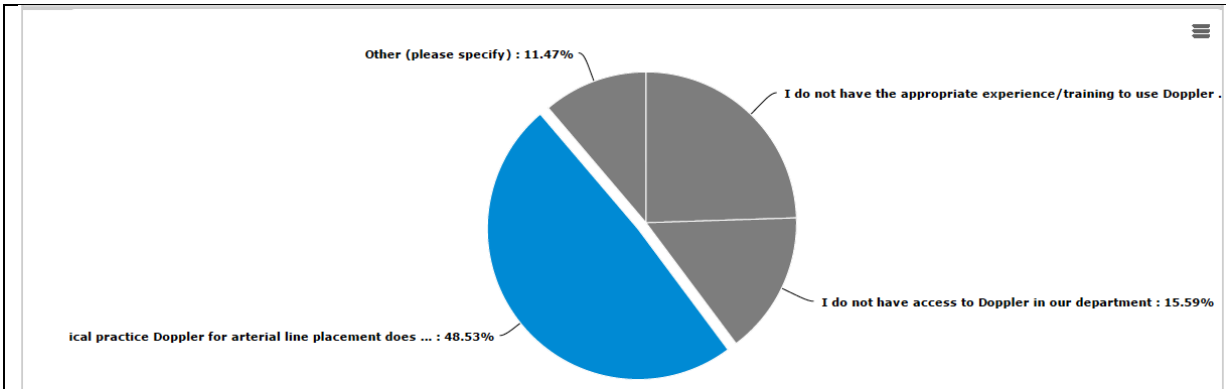
"You use Doppler (acoustic signal) "Most of the time" for arterial cannulation in children because) multiple answers possible"



Answer	Count	Percent
1. It is superior to other techniques to detect anatomical variations	33	22.76%
2. Teaching interest	10	6.90%
3. The learning curve is faster than with other techniques	3	2.07%
4. **I have a higher success rate to cannulate the artery than with other techniques**	53	36.55%
5. I need less time to cannulate the artery than with other techniques	37	25.52%
6. Other (please specifiy)	9	6.21%
Total	145	100%

Question 19 (branching Q17 – answer "Never")

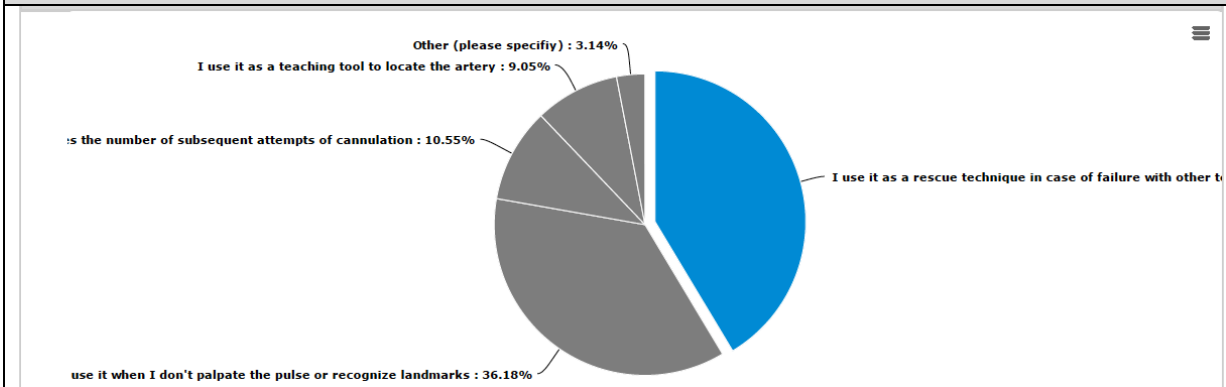
"You "Never" use Doppler (acoustic signal) for arterial cannulation in children because) multiple answers possible"



	Answer	Count	Percent
1.	I do not have the appropriate experience/training to use Doppler for arterial line placement	83	24.41%
2.	I do not have access to Doppler in our department	53	15.59%
3.	**In my clinical practice Doppler for arterial line placement does not offers any advantages over other techniques**	165	48.53%
4.	Other (please specify)	39	11.47%
	Total	340	100%

Question 20 (branching Q17 – answer "Occasionally")

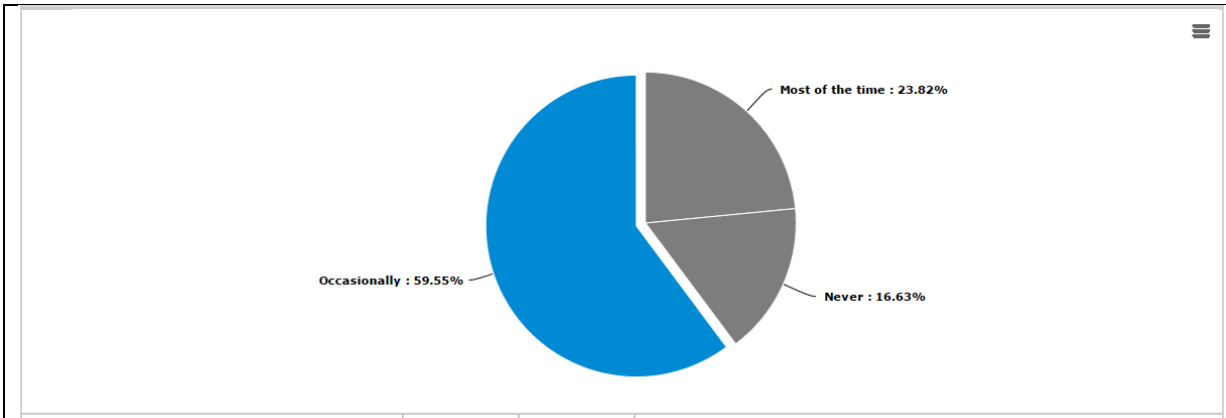
"You "Occasionally" use Doppler (acoustic signal) for arterial cannulation in children because) multiple answers possible"



	Answer	Count	Percent
1.	**I use it as a rescue technique in case of failure with other techniques**	327	41.08%
2.	I use it when I don't palpate the pulse or recognize landmarks	288	36.18%
3.	It decreases the number of subsequent attempts of cannulation	84	10.55%
4.	I use it as a teaching tool to locate the artery	72	9.05%
5.	Other (please specifiy)	25	3.14%
	Total	796	100%

Question 21

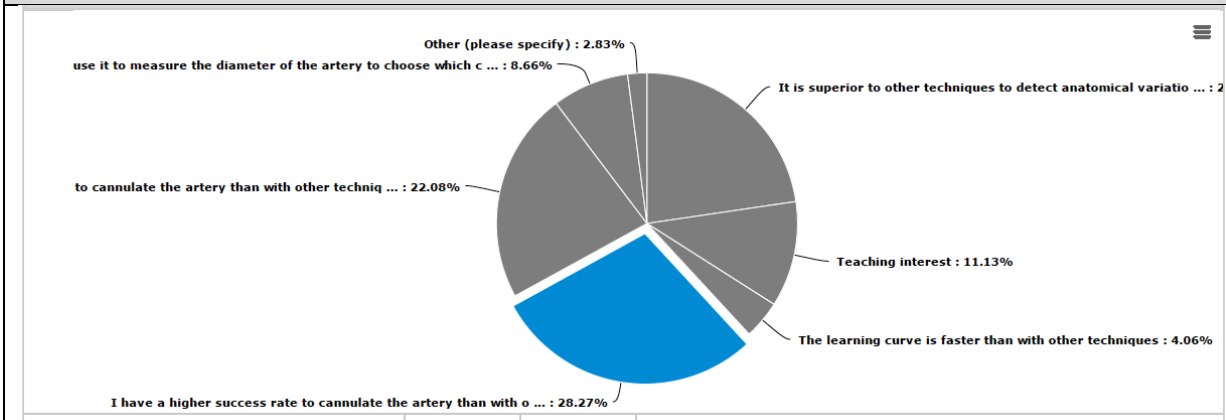
"How often do you use 2D (2 Dimensions) Ultrasound to assist arterial line placement?" **



Answer	Count	Percent
1. Most of the time	212	23.82%
2. Never	148	16.63%
3. Occasionally	530	59.55%
Total	890	100%

Question 22 (branching Q21 – answer "Most of the time")

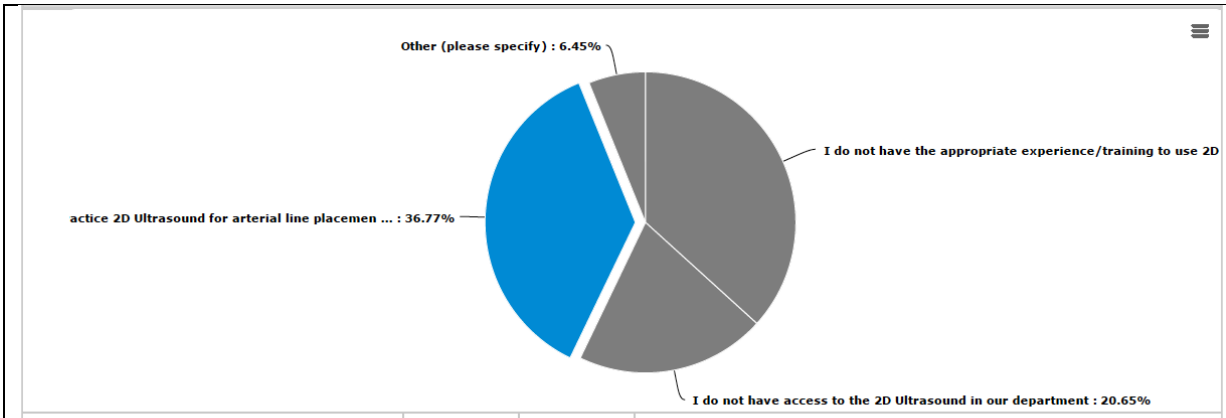
"You use 2D Ultrasound "Most of the time" for arterial cannulation in children because (multiple answers possible)"



Answer	Count	Percent
1. It is superior to other techniques to detect anatomical variations	130	22.97%
2. Teaching interest	63	11.13%
3. The learning curve is faster than with other techniques	23	4.06%
4. I have a higher success rate to cannulate the artery than with other techniques	**160**	**28.27%**
5. I need less time to cannulate the artery than with other techniques	125	22.08%
6. I use it to measure the diameter of the artery to choose which catheter size to insert	49	8.66%
7. Other (please specify)	16	2.83%
Total	566	100%

Question 23 (branching Q21 – answer "Never")

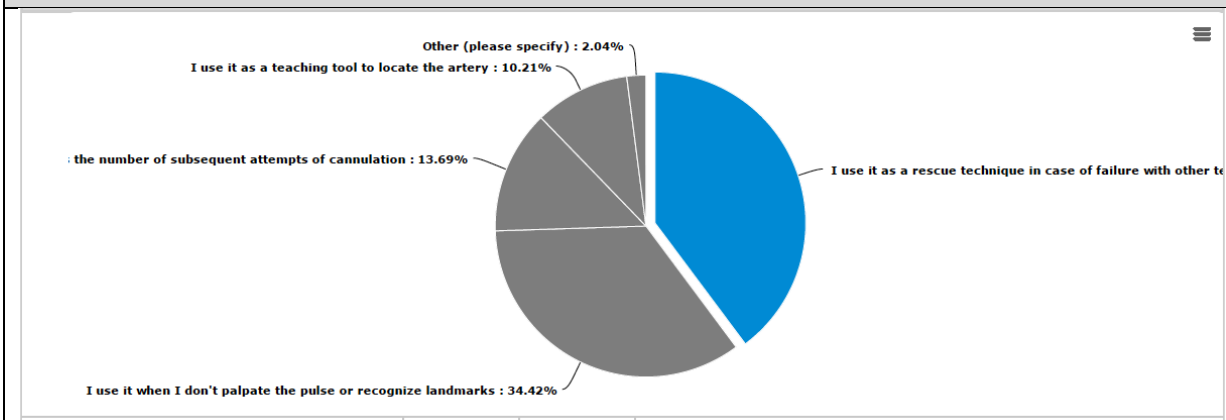
"You "Never" use 2D Ultrasound for arterial cannulation in children because (multiple answers possible)"



	Answer	Count	Percent
1.	I do not have the appropriate experience/training to use 2D Ultrasound for arterial line placement	56	36.13%
2.	I do not have access to the 2D Ultrasound in our department	32	20.65%
3.	**In my clinical practice 2D Ultrasound for arterial line placement does not offers any advantages over other techniques**	**57**	**36.77%**
4.	Other (please specify)	10	6.45%
	Total	**155**	**100%**

Question 24 (branching Q21 – answer "Occasionally")

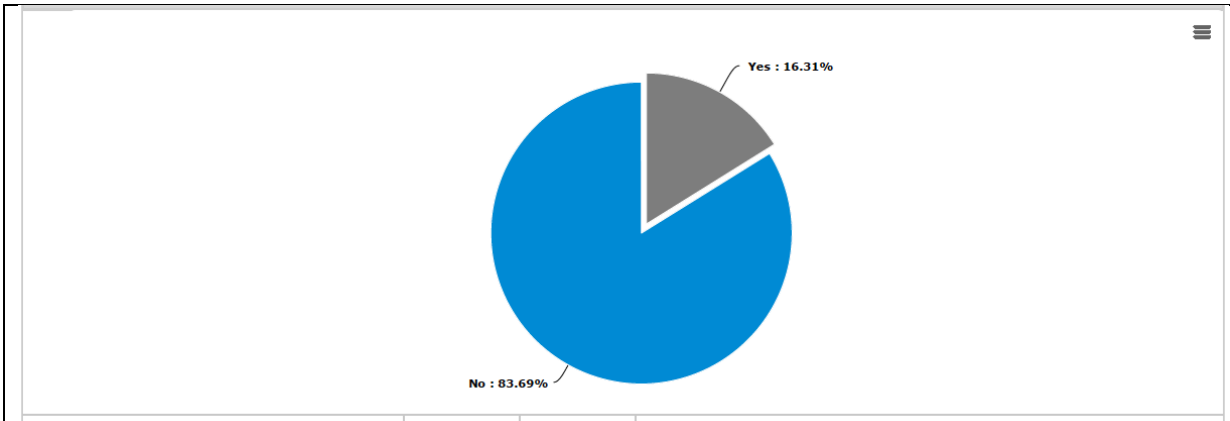
"You "Occasionally" use 2D Ultrasound "Most of the time" for arterial cannulation in children because (multiple answers possible)"



	Answer	Count	Percent
1.	**I use it as a rescue technique in case of failure with other techniques**	**388**	**39.63%**
2.	I use it when I don't palpate the pulse or recognize landmarks	337	34.42%
3.	It decreases the number of subsequent attempts of cannulation	134	13.69%
4.	I use it as a teaching tool to locate the artery	100	10.21%
5.	Other (please specify)	20	2.04%
	Total	**979**	**100%**

Question 25

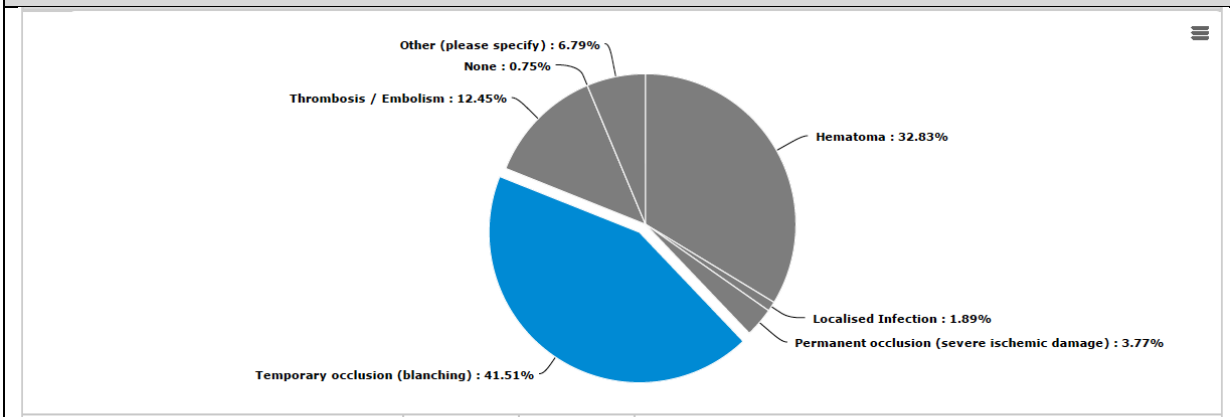
"In the past two years, did you experienced complications related to arterial line cannulation from the time of its placement to its removal?"



Answer	Count	Percent
1. Yes	144	16.31%
2. **No**	739	83.69%
3. I prefer not answering	0	0.00%
Total	883	100%

Question 26 (branching Q25 – answer "Yes")

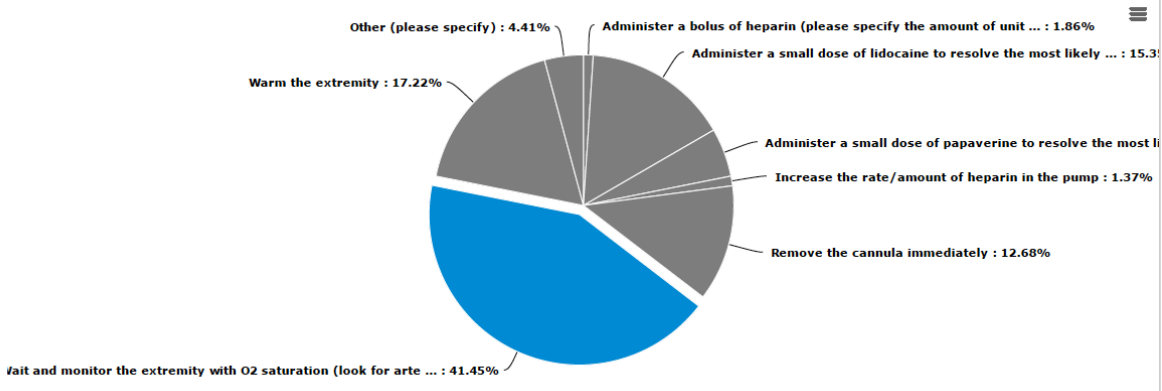
"What type of complications related arterial cannulation did you experience (multiple answers possible)?"



Answer	Count	Percent
1. Hematoma	87	32.83%
2. Localised Infection	5	1.89%
3. Nerve injury	0	0.00%
4. Permanent occlusion (severe ischemic damage)	10	3.77%
5. **Temporary occlusion (blanching)**	110	41.51%
6. Thrombosis / Embolism	33	12.45%
7. None	2	0.75%
8. Other (please specify)	18	6.79%
Total	265	100%

Question 27

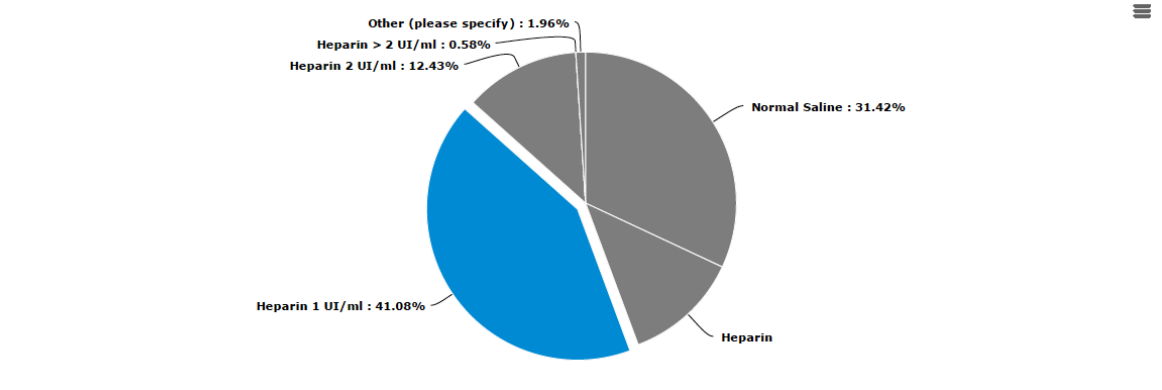
"What would you usually do in case of blanching of the extremity just after an uneventful cannulation (multiple answers possible)?"



Answer	Count	Percent
1. Administer a bolus of heparin (please specify the amount of units under "other")	30	1.86%
2. Administer a small dose of lidocaine to resolve the most likely vasospasm	247	15.35%
3. Administer a small dose of papaverine to resolve the most likely vasospasm	91	5.66%
4. Increase the rate/amount of heparin in the pump	22	1.37%
5. Remove the cannula immediately	204	12.68%
6. **Wait and monitor the extremity with O2 saturation (look for arterial wave and saturation)**	**667**	**41.45%**
7. Warm the extremity	277	17.22%
8. Other (please specify)	71	4.41%
Total	**1609**	**100%**

Question 28

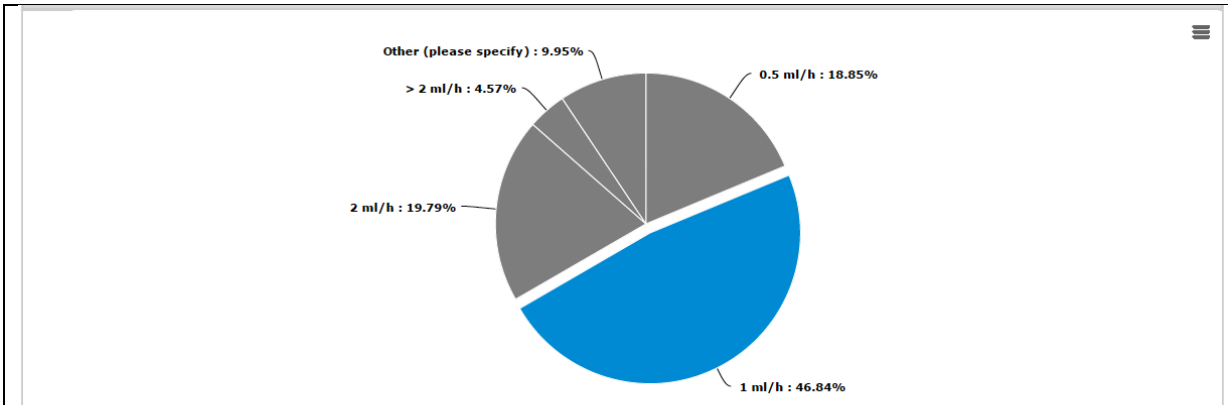
"What solution and/or concentration of heparin do you use to keep patent the arterial line (KVO) in children < 10 Kg?"



Answer	Count	Percent
1. Normal Saline	273	31.42%
2. Heparin < 1 UI/ml	109	12.54%
3. **Heparin 1 UI/ml**	**357**	**41.08%**
4. Heparin 2 UI/ml	108	12.43%
5. Heparin > 2 UI/ml	5	0.58%
6. Other (please specify)	17	1.96%
Total	**869**	**100%**

Question 29

"Please indicate the minimal rate of infusion you run to keep the arterial line patent (ml/h) in children < 10 Kg?"



Answer	Count	Percent
1. 0.5 ml/h	161	18.85%
2. 1 ml/h	400	46.84%
3. 2 ml/h	169	19.79%
4. > 2 ml/h	39	4.57%
5. Other (please specify)	85	9.95%
Total	854	100%

Question 30

"Thank you for taking part to this survey. Do you have any comments /suggestions regarding it?"

See reporting and detailed comments in section 9.4.3.

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5. DISCUSSION

5.1. General discussion

One of the main finding of this survey was that the majority of responders did not have institutional written policies for paediatric arterial cannulation. Ideally, guidelines should help to prevent complications, increase success rate, and would be relevant to all practitioners, as it has been demonstrated for central venous access (Kumar A et al., 2009; Troianos CA et al., 2011) (**Figure A**).

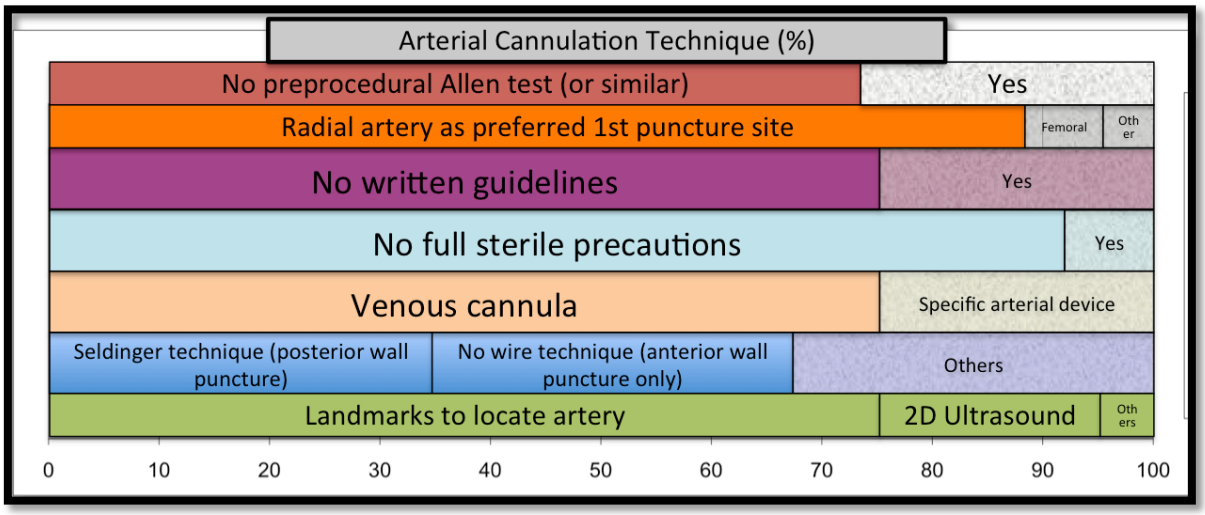


Figure A: summary of arterial cannulation technique (Line 1: Allen test? Line 2: Primary site of cannulation? Line 3: Written guidelines? Line 4: Full sterile precautions? Line 5: Device used? Line 6: Technique of punction? Line 7: Technique of location?)

Although the practice varies, most responders use regular venous catheters, prefer the radial artery as the primary site, change limb in the case of failure at the primary site, and prefer anatomical landmarks as the primary method to locate the artery (**Figure B**). They use 2D US “occasionally" and mainly as a rescue technique, but those who used it "most of the time” reported higher success rate and faster cannulation.

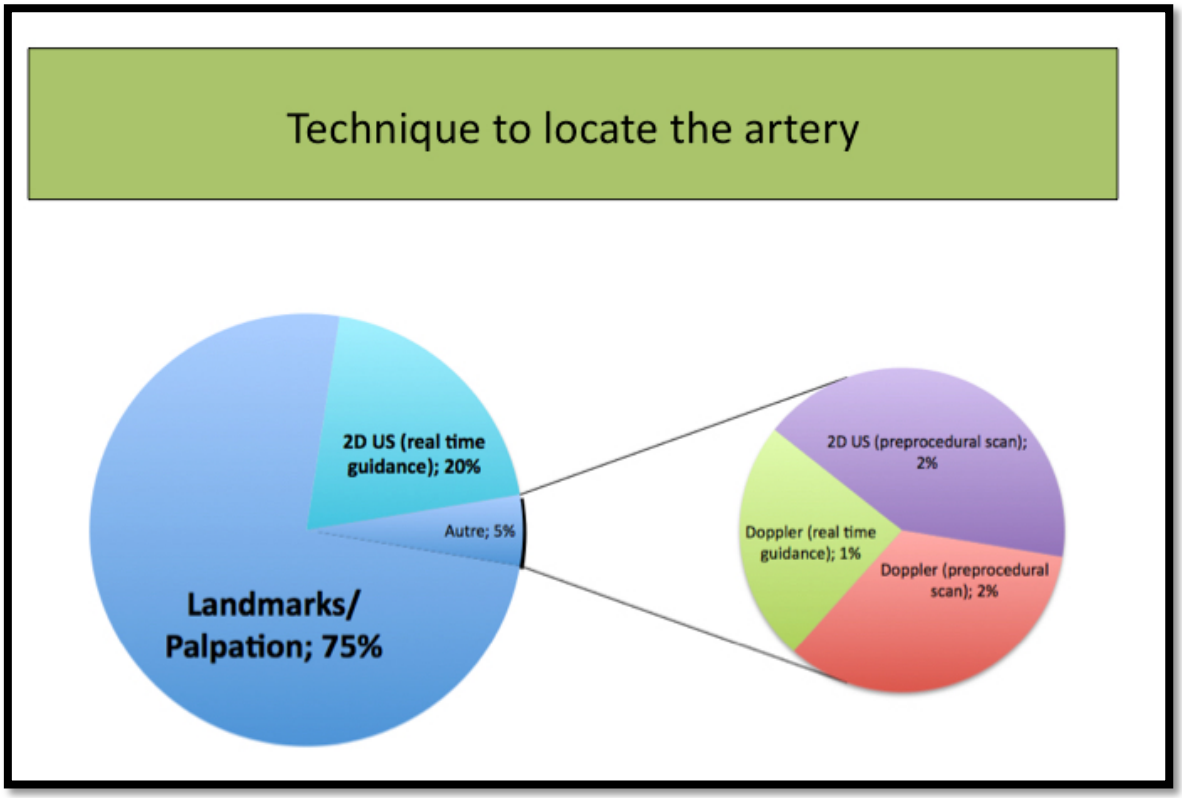


Figure B: Use of ultrasound to assist location or cannulation

Not surprisingly, the radial artery represents the preferred site for cannulation, which is in line with other environments such as the paediatric intensive care units (Smith-Wright D et al., 1984; Brotschi B et al., 2011). The radial artery is widely considered safe (Smith-Wright D et al., 1984), having a higher risk of temporary occlusion (from 1.5 to 35%, on average 20%), but a low risk of permanent occlusion (0.09%) and extremely rare permanent ischemic events (Scheer B et al., 2002). The presence of the ulnar arterial flow is considered adequate to perfuse the hand in case of radial artery occlusion, and the Allen's test is still recommended in major paediatric textbooks to assess this collateral flow (Kohonen M et al., 2007; Shah A et al., 2015). However, studies in children are lacking and the utility of the test is now questioned due to its low sensitivity (Kohonen M et al., 2007; Shah A et al., 2015). In our survey, most responders stated that they do not perform it in the daily practice.

The femoral site as second choice (**Figure C**) is also consistent with textbooks and clinical practice because of its accessibility and reliability for blood pressure monitoring, even in case of hemodynamic instability or cardiac conditions (Cho HJ et al., 2017; Chauhan S et al., 2000).

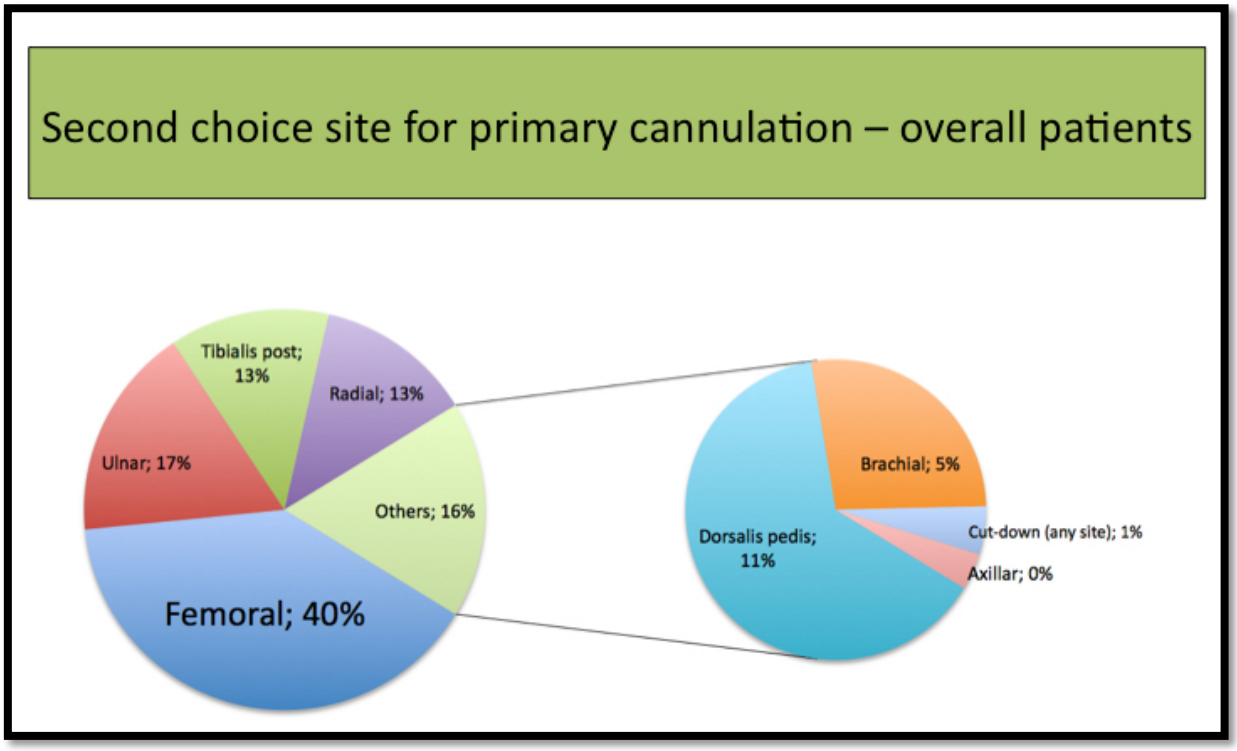


Figure C: Second choice for arterial cannulation.

The advantages of the radial site over others are the ease of fixation and lower risk of catheter displacement/dislodgment compared to brachial or axillary site for example. The rate of infection is also lower than the femoral one and access to the puncture site is easier for monitoring or blood sample removal. The significantly high volume of publications related to radial site cannulation is indicative of its popularity.

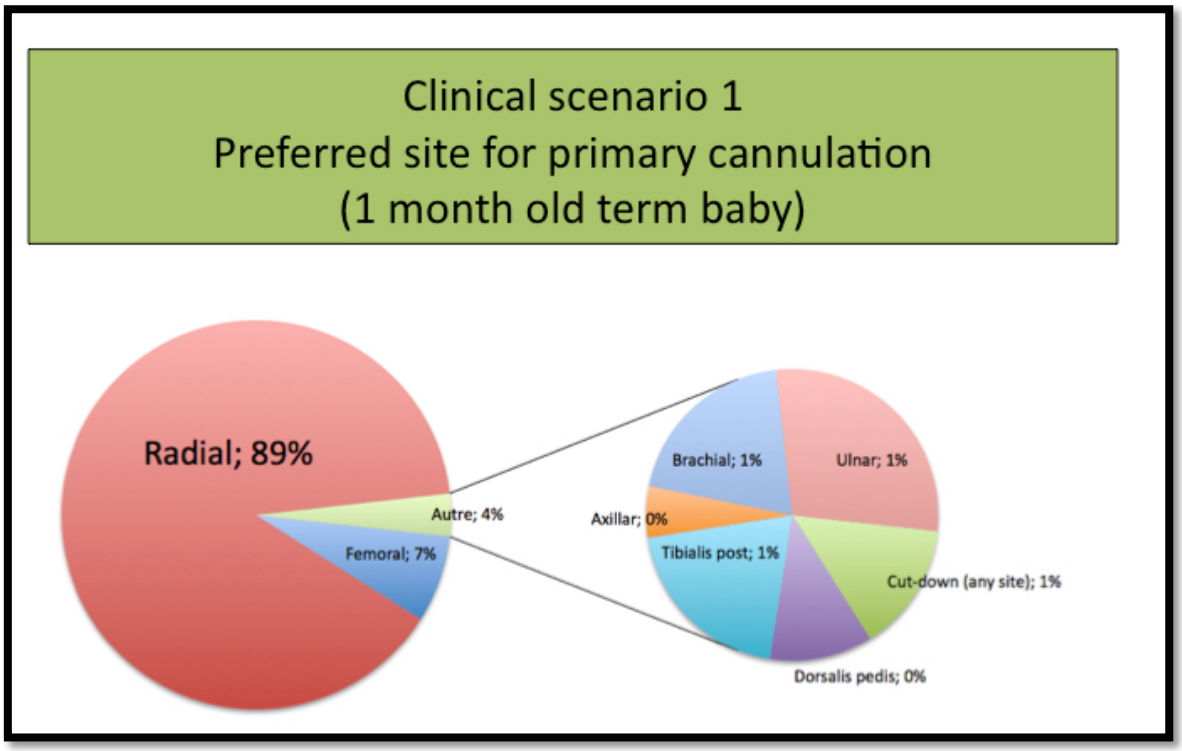
Surprisingly, the ulnar artery usually has a bigger internal diameter but this site is not as popular as the radial site. We could not give an explanation for this based on the survey. However, the ulnar artery is more mobile in the subcutaneous tissue, hence more difficult to puncture and practitioners may be reluctant to risk occluding the biggest vascular supply to the palm (Brezinski M et al., 2009). Another explanation is the close anatomical proximity of the ulnar nerve to the artery, thus, in theory, putting it at risk of puncture when only landmarks technique is used.

The femoral artery was reported as the first choice of cannulation by only 7% of the responders. The temporary occlusion of the femoral artery is less common than the radial artery (1.5%), but the risk of permanent ischemia requiring amputation is almost two-fold higher (0.18%)(Scheer B et al., 2002). Children with congenital heart defects seem more vulnerable to permanent ischemic insults and subsequent limb dystrophia (Rizzi M et al., 2016). This risk may be related to greater risk of episodes of hypotension during surgery and post-operatively and to vascular abnormalities. Down syndrome patients have a specific, yet unexplained, vascular sensitivity and higher propensity to arterial spasms. They also often have underdeveloped arteries for their age, resulting in more difficult cannulation, higher occlusion (transient or permanent) and complication rates (Sulemanji DS et al., 2009).

Surprisingly, distal arteries such as the dorsalis pedis and tibialis posterior were used more often than the axillary and the brachial arteries**.** The dorsalis pedis and tibialis posterior arteries are rarely chosen in critically ill patients due to the lower level of reliability and shorter lifespan (Scheer B et al., 2002).

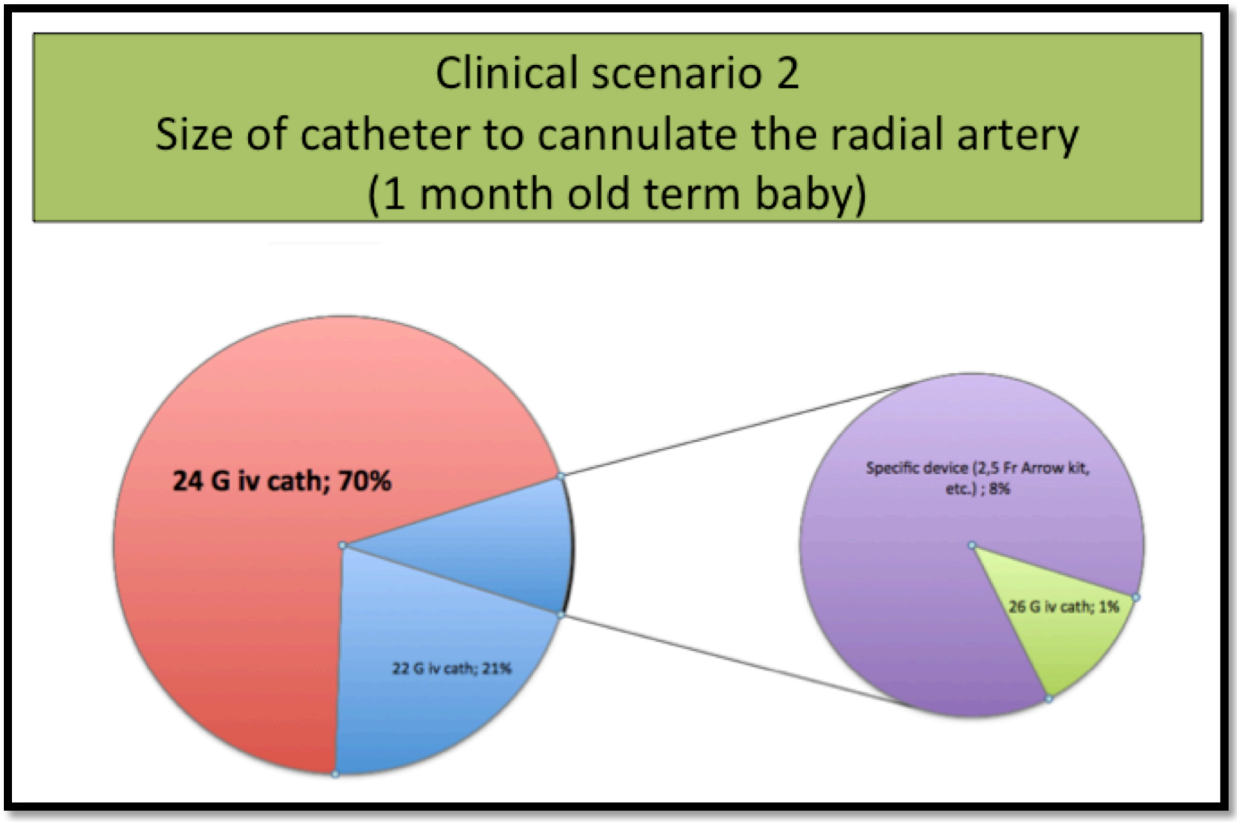
Regarding the axillary artery, the risk of temporary occlusion and permanent ischemic events are similar to the femoral artery (Scheer B et al., 2002). In comparison to the axillary artery, the brachial artery does not have important collaterals, is close to major motor nerves, and the high mobility of the catheter during arm flexion/extension may cause injury of the intima and subsequent thrombosis (Detaille T et al., 2010). For all those reasons, the majority of practitioners are reluctant to use it, even though one study did not show a higher risk of complications when skilled hands manage that site of insertion (Scheer B et al., 2002; Schindler E et al., 2005).

With regard to arterial cannulation in infants, responders prefer the radial site as primary choice (**Clinical scenario 1**) then femoral.



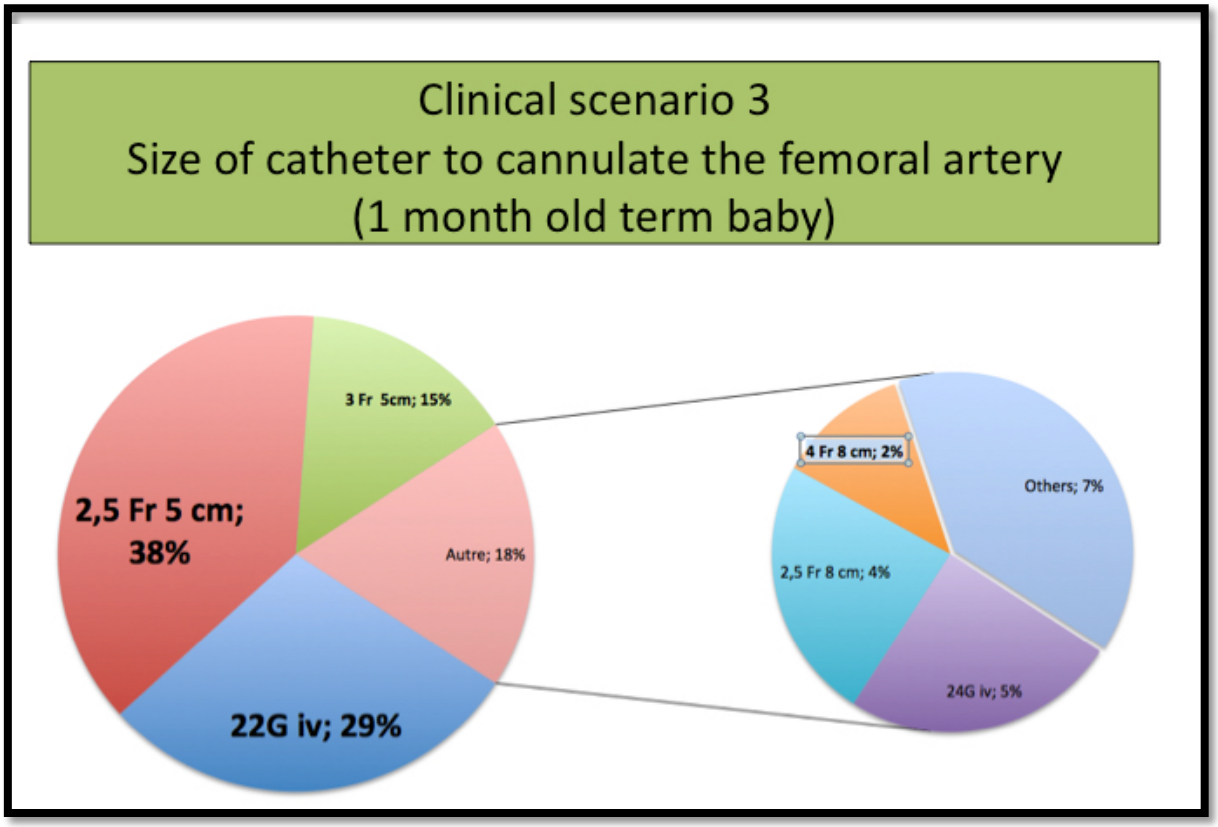
Clinical scenario 1

As far as the size of catheter is concerned, 22G and 24G intravenous catheters are preferred for the radial artery (**Clinical scenario 2**), which is consistent with a previous prospective study (Schindler E et al., 2005).



Clinical scenario 2

However, a recent case report pointed out that in children <1 year, a 22G cannula may occupy more than 30% of the arterial lumen, and therefore increase the risk of complications (Varga EQ et al., 2013). Similarly, 2.5Fr and 22G femoral catheters have been associated with higher risk of thrombosis (Dumond AA et al., 2012), but they are used by two thirds of our responders (**Clinical scenario 3**) without an evident high reporting of femoral thrombosis. Of note, smaller gauge catheters (like 24 G) would be too short for the femoral site and at high risk of dislodgement, so the choice is constricted between contingencies of appropriate sizing and length.



Clinical scenario 3

Comparing cannulation techniques, the “puncturing and threading” technique is more successful in small children (Yildrim V et al., 2006) when associated with a guide-wire, while in adults or older children “puncturing and threading” or “going through and draw back” techniques don’t give advantages either with or without a guide-wire (De Oliveira GS et al., 2014). This probably explains why the “puncturing and threading" without the guide-wire technique is two times more common among respondents than guidewire (often referred as Seldinger) assisted “puncturing and threading” techniques. Similar, but reverse, results were obtained with respect to the guide-wire assisted "going through and draw back" technique. In adults, the guide-wire assisted "going through and draw back" technique does not give advantages when compared to “puncturing and threading" without the guide-wire (De Oliveira GS et al., 2014). In children, the “puncturing and threading" technique is more successful when associated with guide-wire use (Yildrim V et al., 2006).

Anatomical landmarks remain the preferred technique for arterial localization among responders. The 2D US is mostly used as rescue technique and the Acoustic Doppler seems to be outdated (**Figure D**).

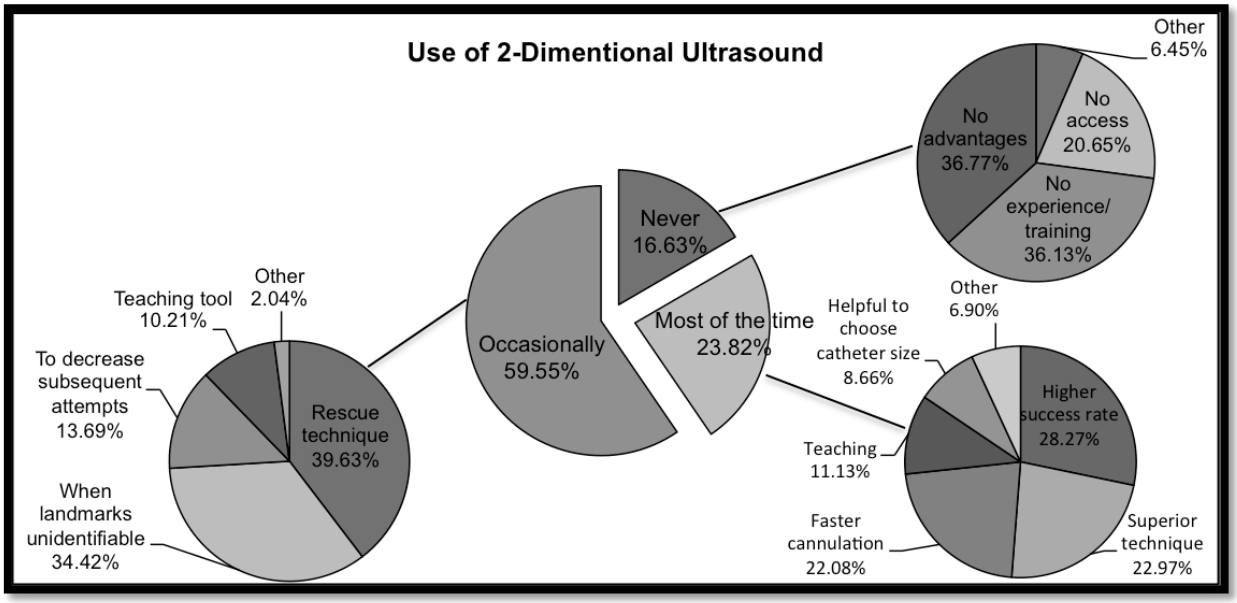


Figure D: Use of 2D Ultrasound

If we compare the use of 2D US to years of experience, days in paediatric OR and number of arterial lines inserted, the lack of experience with 2D US is an important reason preventing its use. Interestingly, there seem to be a discrepancy between the years of experience or days in paediatric OR and the number of arterial lines inserted per year. The higher, the years of experience in paediatric anaesthesia, the lower respondents acknowledge to use 2D US primarily. On the opposite, the more frequently they insert arterial lines per month, the more often they tend to use 2D US (**Figure E**). Same result when comparing the days of paediatric anaesthesia per month (**Figure F**).

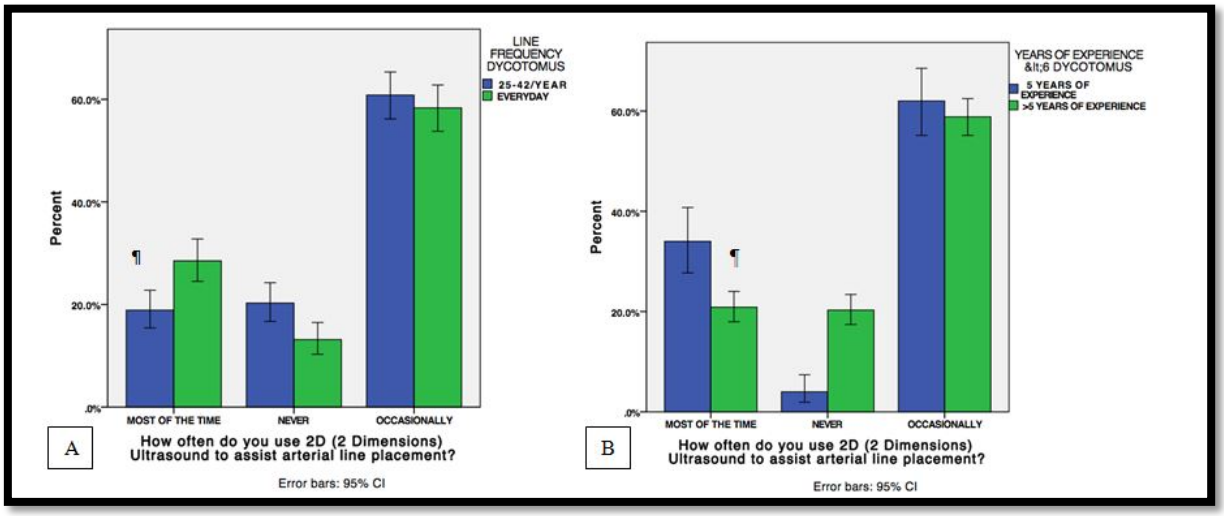


Figure E: Use of 2D ultrasound utilization compared to arterial exposure (A) and years of experience in paediatrics (B). (¶ Kruskal-Wallis test, p<0.001).

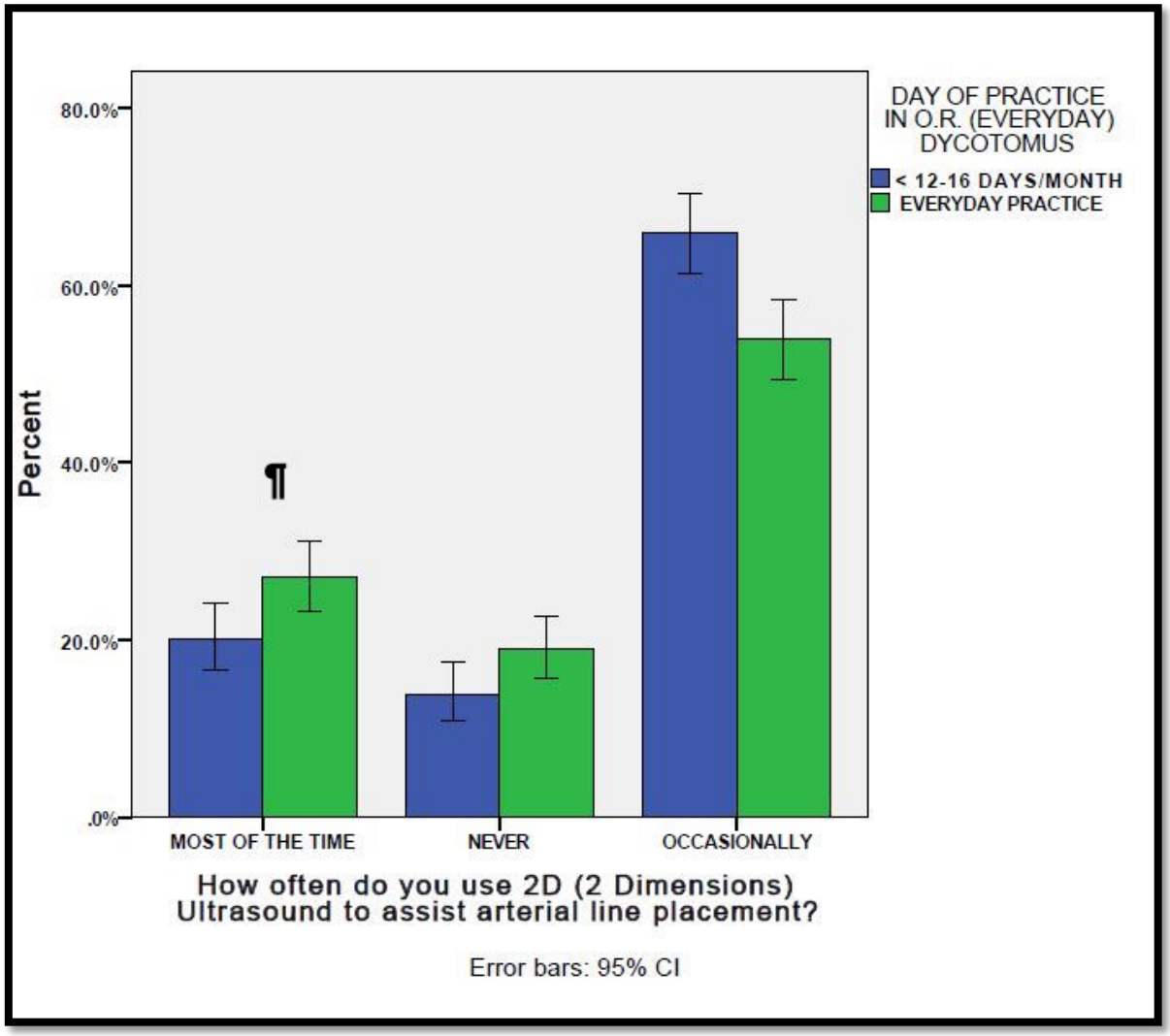


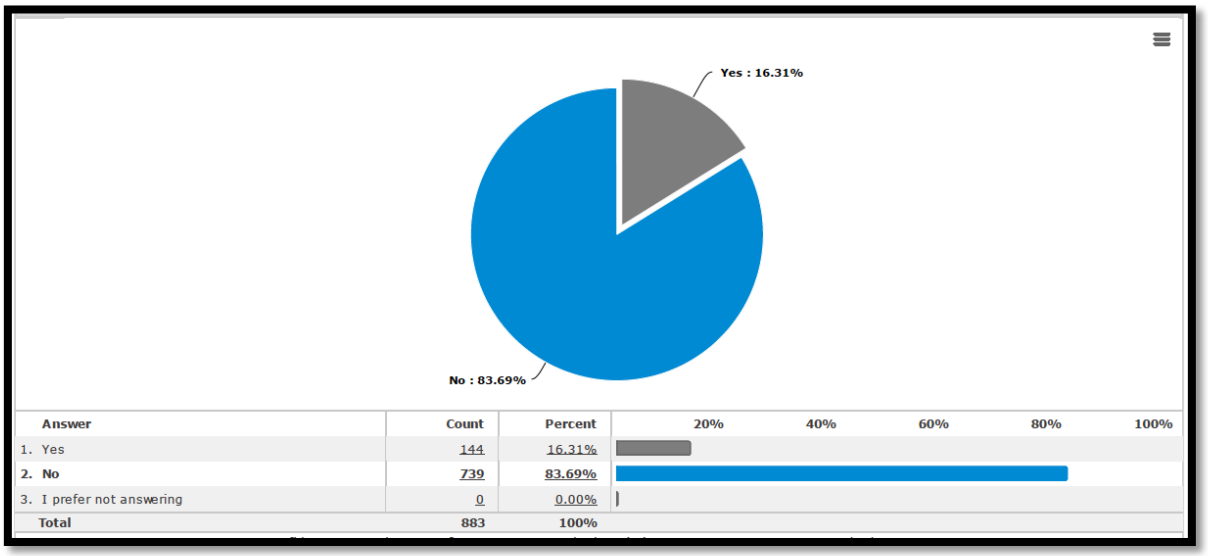
Figure F: Comparison between low versus everyday practice of paediatric anaesthesia (¶McNemar test, p<0.001)

This apparent contradiction may be due to differences in practitioners' generation and activities. Unfortunately, the survey was lacking data to fully analyze those discoveries and our questionnaire was not designed to compare subspecialties and place of work (university settings, general hospital, cardiac teams, general surgeries) to the use of ultrasound. Indeed, more experienced practitioners are probably from an previous generation and have learned to insert arterial lines using only landmarks, thus have transitioned secondarily to ultrasound. Practitioners inserting arterial lines "everyday" may be faced to more complex cases, like congenital cardiac, multiple previous cannulations attempts or cutdowns, thrombosis, patients under ECMO or Ventricular Assist Device (non-pulsatile arterial flow) thus requiring 2D US more frequently because of specific patient's challenges, without necessarily many of years of experience.

The 2D US has been associated with an improved success rate at the first attempt in both adults and children (Gao YB et al., 2015; Troianos CA et al., 2012). However, it requires specific training (Ganesh A et al., 2009; Khilnani PK et al., 2013), hence its routine use is not recommended by the American Society of Echocardiography and the Society of Cardiovascular Anaesthesiologists (Troinaos CA et al., 2012). Moreover, the cannulation of

very superficial arteries (< 2mm depth) remains challenging even with the utilization of the ultrasound (Nakayama Y et al., 2014). It is therefore reasonable to presume that a certain level of experience is required before using the 2D US with confidence (Aouad MT et al., 2010).

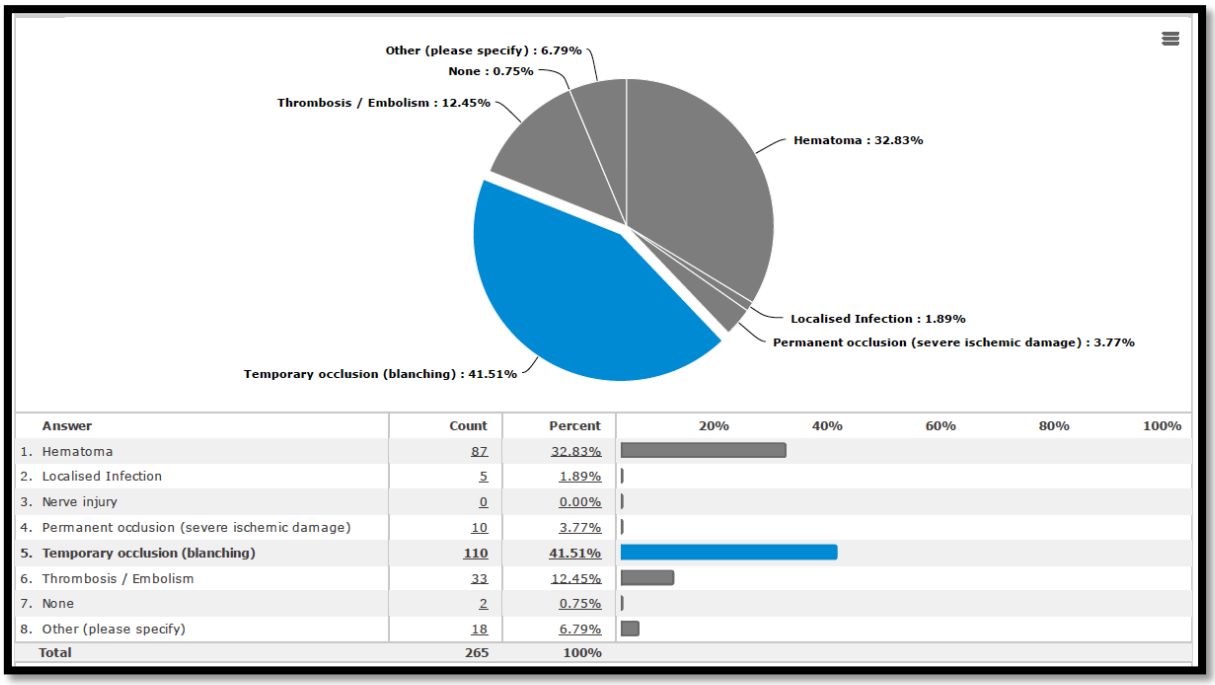
Consistent with the literature, one in five responders in our survey reported complications in the previous two years (**Figure G**).



Answer	Count	Percent
1. Yes	144	16.31%
2. No	739	83.69%
3. I prefer not answering	0	0.00%
Total	883	100%

Figure G: Frequency of reported complications in the past two years

The incidence of temporary occlusion, hematoma and localized infections are in line with published data (Scheer B et al., 2002; Smith-Wright D et al., 1984; Dumond AA et al., 2012). On the other hand, permanent arterial occlusion is reported by 4% of responders, which is higher than expected (Scheer B et al., 2002; Rizzi M et al., 2016; Detaille T et al., 2010) (**Figure H**).



Answer	Count	Percent
1. Hematoma	87	32.83%
2. Localised Infection	5	1.89%
3. Nerve injury	0	0.00%
4. Permanent occlusion (severe ischemic damage)	10	3.77%
5. Temporary occlusion (blanching)	110	41.51%
6. Thrombosis / Embolism	33	12.45%
7. None	2	0.75%
8. Other (please specify)	18	6.79%
Total	265	100%

Figure H: Repartition of respective reported complications

This could be explained by two reasons: the use of relatively big catheters or the KAO regimen. Some of the responders, in fact, may use catheters that are relatively too big (Dumond AA et al., 2012; Detaille T et al., 2010) or do not use heparin, which may be more beneficial than normal saline for a catheter usage longer than 48 hours (Kordzadeh A et al., 2013). Of note, watchful waiting and monitoring is described as the most common management in case of a blanching extremity (**Figure I**).

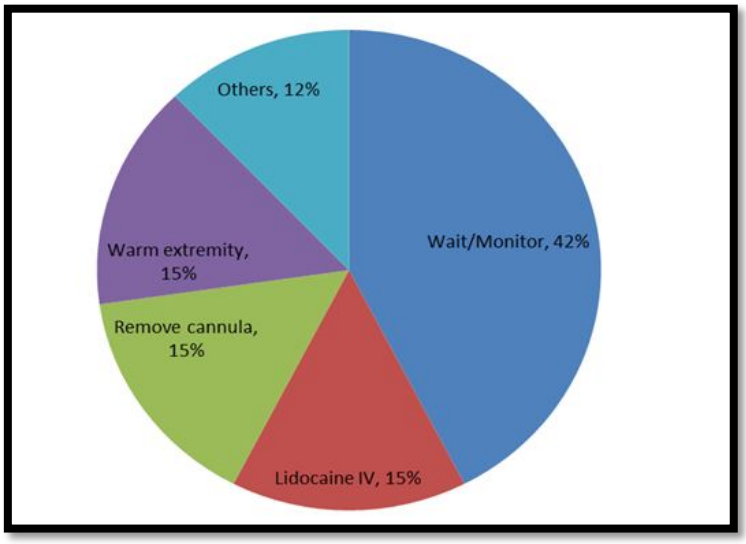


Figure I: Management of complications

Anaesthesiologists with an experience of ≥ 25 arterial lines/year reported complications more frequently. This may be due to the fact that those who put in more arterial lines are usually involved in the management of more complex cases who may be are at high risk of catheter occlusion, such as congenital heart disease (Rizzi M et al., 2016) and newborns (Brotschi B et al., 2011) (**Figure J**).

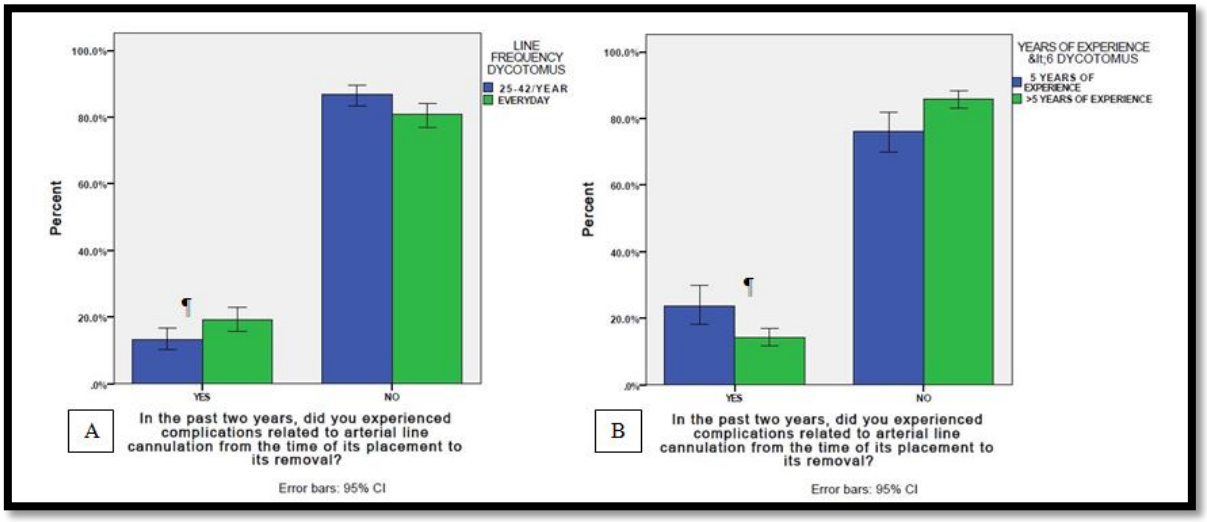


Figure J: Percentage of responders who declare complications according to cannulation frequency (A) and years of experience (B). (¶McNemar test, p<0.001).

5.2. Evaluation of the free comments box (see detailed comment in chapter 9.4.2)

- **Question 7: "Do you have local written guidelines for arterial cannulation (i.e. technique, dressing, sterile precautions)?**"

Answers were very diverse, mainly showing a lack of full sterile precautions that is gown, hat and sterile gloves. Chlorexidine 2% seemed widely used which is advantageous in neonates as they has shown higher transcutaneous absorption of polyvidone iodine with potential thyroid disbalance. SPA members seemed to follow more CDC guidelines. Interestingly, some respondents acknowledged to use premade arterial kits with drapes, which promotes standardization thus enhance sterility and lowers total procedure time.

- **Question 8: "What medical device do you usually prefer for arterial cannulation in paediatric patients?"**

For specific arterial device, "Arrow®", "Cook®" or "Vygon®" ("Leadercath®") come more often and "Abbocath®" or "Jelco®" for venous device used in arterial position. Interestingly, nowadays, the material that are constructed arterial catheter of is not a matter of discussion, nevertheless this debate is not new. Roughness of material seems to be directly linked to thrombogenicity potential (Hecker JF, 1985; Roberts GM, 1977) and polyethylene / PTFE catheters display a higher thrombogenic potential than silicone catheters for example. Unfortunately, silicone catheters are less mechanically resistant (Wildgruber M, 2016).

- **Question 11 ("baby scenario 2"): "In case you put a radial arterial line in a full term 1 month old baby, what size would you choose?"**

With specific arterial catheters, some participants declared to insert mostly 2.5 Fr size, between 3 cm and 2.5 cm length. The 2.5 Fr diameter is sometimes presented as equal to 22G size, however 22G has an external diameter of 0.711mm and 2.5 Fr equals 0.825mm, which is a 13% increase in diameter.

Related to circumference this small difference of catheter diameter may lead to a complete occlusion of the vessel. Varga et al. (2013) has shown that the internal diameter of the radial artery of children up to 4 years is less than 2 mm and as small as 0.4 mm, that is smaller than a 24 G catheter (0.559 mm) (see Comparison chart between Gauge and French scales – Addendum). If we follow Bedford RF et al. (1977), trying to insert catheters not larger than 20% of the internal lumen of the chosen vessel, this would be impossible in babies and even older children and lead systematic occlusion. However, the reported rates of complications in our survey, as well as the rate of occlusion in the literature, are not consistent with that finding. Probably, inserting a large catheter but removing it early may avoid long lasting occlusion, however our survey was not designed to assess the length of stay of arterial catheters.

- **Question 12 ("baby scenario 3"): "In case you put a femoral arterial line in a full term 1 month old baby, what size of catheter would you use?"**

Participants' comments show that they insert 22G and 2.5 Fr catheters, up to 3 Fr (1 mm of diameter). Some have special length catheters with small Gauges (like 24) but extra length (up to 8 cm). This is very interesting as it allows to insert a catheter of appropriate diameter but with a length suitable to the femoral site. Indeed, the femoral artery lies deeper than the radial one and a too short catheter would definitively too easily dislodged, with potential complications (hematoma, etc.).

- **Question 14 ("baby scenario 3"): "In cooperative patients and prior to arterial puncturing at radial/ulnar level, do you assess collateral perfusion (most of the time)? »**

Surprisingly, we didn't get as much comments on that controversial topic as we would have expected. However, some comments were interesting, mostly presenting 2D US as a potential tool to evaluate arterial collateral flow, especially in babies, were the vessels of the palmar arch may be followed from one end to another.

- **Question 16: "To locate the artery, what technique do you use most of the time?"**

Not may comments. Transillumination has been forgotten as a preprocedural aid or even during procedure.

- **Question 18 + 19 + 20 + 22 + 23 + 24**

Comments have already been analyzed extensively in the results section

- **Question 26: "What type of complications related to arterial line cannulation did you experience (multiple answers possible)?"**

Few comments came out of that question's free comments box, mainly about some case reports, like catheter lost in patient after inadvertently being cut, blood stream infection, inadvertent intra-arterial medication administration (without sequelae). All those comments emphasize the need of guidelines and standardization of procedures.

- **Question 27: "What would you usually do in case of blanching of the extremity just after an uneventful cannulation? (multiple answers possible) »**

Most of respondents answered they would wait and monitor carefully the limb, before removing the cannula in case of persistent blanching. The second most used regimen were lidocaine infusion or papaverine in order to promote vasodilatation.
Some would warm the extremity but may put the limb at risk of subsequent cutaneous damage as warmth would be applied on an already jeopardized skin. Interestingly, only one person added the comment he/she would warm the controlateral extremity. This will enhance a reflex vasodilatation, mediated through sympathetic system (Ramasethu J, 2005).
Interestingly, nobody proposed a topical nitroglycerine ointment to alleviate the ischemic vasoconstriction induced by the arterial catheter (Vasquez P, 2003; Mosalli R, 2013).

- **Question 28: "What solution and / or concentration of heparin do you use to keep patent the arterial line (KVO) in children < 10 Kg?"**

The diversity of comments puts light on the controversy between heparin containing solution or normal saline ones. Up to now there hasn't been a definitive statement choosing between those two regimens, each one having its own advantages and disadvantages. This topic is extending beyond the topic of arterial line insertion.

- **<u>Question 29</u>: "Please indicate the minimal rate of infusion to keep the arterial line patent (ml/h) in children < 10 Kg?"**

The most common infusion rate is 1ml/h. Of note it is not unusual to read comments describing the use of pressurized bags rather then infusion pumps to maintain line patency. This is relatively concerning as pressurized bags have been implicated in adverse events and fluid overload. Indeed, the usual rate of infusion of pressurized bags (300mmHg bags) is around 3.5 ml/h. This represents 85 ml/day, without any additional flushes. This extra amount of fluids may be deleterious in sick neonates during long-term use in the neonatal and paediatric intensive care unit, although probably negligible during anaesthesia (Cornelius A, 2002).

The critical rate of infusion during flushes has been evaluated at 0.5 ml/sec, as a higher rate has been linked to blood pressure elevation and, more concerning, retrograde flow in arterial system, with possible embolization of air or material (Butt WW, 1985). An in-vitro study showed that standard pressurized bags may produce higher infusion rate during flushing, thus may be used with much caution (Cornelius A, Int Care Med 2002). The in-vivo study by the same group, following those results, on the opposite demonstrated that fast bolus flushing (1-2 seconds) from pressurized bags systems, using flow regulating device, may be applied during neonatal and paediatric anaesthesia without delivering uncontrolled amounts of fluids or fast infusion rate as long as the bag pressure is limited under 300 mmHg, ideally 100 mmHg (Cornelius A et al., 2002).

- **<u>Question 30</u>: "Thank you for taking part to this survey. Do you have any comments/suggestions regarding it? »**

Several comments arouse due to technical difficulties during the questionnaire process. For example, several respondents would have been satisfied to hit a "back" button, in order to correct an answer (either a wrong manipulation or a change of mind). Others mentioned a error in the "drag and drop" process of question 14 (not able to correctly arrange items), however the three initial survey evaluation and Montreal Children Hospital departmental testing processes didn't uncover those technical issues.

5.3. <u>Strengths of the survey</u>

This survey is a snapshot of current practices in paediatric arterial cannulation among anaesthesiologists with different levels of training, paediatric experience, and work backgrounds.

The survey was sent to four several western paediatric anaesthesia societies to obtain the most realistic and reliable picture of current practice.

The survey was intentionally focused on practical aspects of daily practice in order to evaluate potentially correctible safety issues where future guidelines can be directed.

5.4. Limitations of the survey.

Our survey has several limitations. First of all, the overall response rate was only 21%, which is below the expectation for a robust survey (Schleyer T et al., 2000), although a sample size of 356 would have been enough to offer a 95% confidence limit with a 5% confidence interval in relation to the 4254 questionnaires that were sent (calculator source: the survey system https://www.surveysystem.com/sscalc.htm).

Indeed, in case of low response rate, it is not possible to know to what extent the non-responders deviate from responders, a bias called “non-response error” (Draugalis JR et al., 2008; Tait AL et al., 2015)). This may be due to the method used to deliver the survey (email versus paper) and not to the quality of the questionnaire, as demonstrated by the fact that it was completed by 76% of those who started it.

It is also possible that the physician’s curiosity to such questionnaire may have been blunted by the nowadays-overwhelming amount of e-surveys received in their mailbox (mailbox syndrome). This is particularly true in the APAGBI society, where they have regular and major national audit, through Internet survey processes. Definitively, the “mailbox box” syndrome was an important determinant of the low response rate in our survey and in surveys in general., doubled with the impression that survey research is an “easy business” (Draugalis JR et al., 2008).

There are some strategies in order to promote people to answer. Typically, a survey is considered as a task that doesn’t bring something concrete and immediate to responders, in other words they need incentives to start the survey and to complete it (Burns KE et al., 2008).

This represents 2 different topics. To start a survey, it needs an attractive introduction letter, a support letter from an official organism (like a directory board) and a survey’s first page that clearly states the objectives of the survey and the amount of time required to complete it. The questionnaire’s first page has to “tease” participants. Definitively, the main issue was on that aspect of human psychology, and we couldn’t control the message sent to each members as the directories’ boards edited it, with the Internet link to the survey’s page.

Technically, when someone decided to click on the link, they were redirected to the first page (introductory page) of our questionnaire. In order to start the survey, they had to accept the conditions, with a declaration of anonymity, ethical concerns, etc. (see supplementary material with the whole survey and questions). When the “I agree” button at the bottom of the introductory page was clicked, the survey was considered “started”. Otherwise, when people were only reading the introductory page, without clicking on the “I agree” button, statistics were only counting as “viewed”, not “started”.

Probably, the email with the link to the survey was not teasing enough as illustrated by the ratio between questionnaires that were sent (4254) and those viewed (1664), which represents only 34%. In other words 2 members on 3 didn’t click on the link to the survey… maybe without even reading the letter of support? Maybe simply deleting an email with the word “survey” in the title? We’ll never know, as again we didn’t have a word on that part of the process. One technique of teasing would have been to propose a monetary (i.e. cash) or non-monetary reward to people taking part to the survey and who have completed it. What

we can find nowadays is a lottery to win “goodies”, like “iPads” and so on. However, such incentives presuppose a substantial budget we didn’t have access to. Maybe vauchers for bookstore (Amazon, etc.) could have represented an intermediate financial solution.
Of note, in order to run a lottery and send prizes to winners, we would have needed to collect participants’ emails, which could have been considered as a privacy violation.
The ratio of questionnaires “viewed” (1664) over those “started” (1171) was around 70%. This statistic tells us that the introductory page was teasing enough (subject treated, ethical consideration) to click on the “I agree” button and start the process.
The ratio of questionnaires that were started (1171) over those completed (899), is called the “completion rate”, which represents approximatively 76%. In consequence, this tells us that the questionnaire in itself was relatively well constructed, interesting enough to go through 26 items and finish it.
Again, very probably, a direct reward like a financial incentive could have augmented both statistics: the ratio of “viewed” over “started” and the completion rate. Incentives have also known drawbacks like introducing a selection bias, pushing people to complete a questionnaire just for the reward, maybe answering to questions not so precisely (Schleyer T et al., 2000).

Secondly, the number of the reminders varied according to the policy of each paediatric society, and this may have affected the response rate, although only in a minor way (Burns KE et al., 2008; Schleyer T et al., 2000). Unfortunately, it was not possible to insist too much on each society for them to follow the reminder guidelines we have edited for the survey. Indeed, in order to respect the autonomy of each societies and the privacy of their members, we had to go through a revision process directed by the directory board of each societies. This board asked us to modify some aspects of the survey (mainly editorial) and gave us some limitations, like the non-access to the mailing list of their respective members. This limitation in particular was a major one, hindering us to personally contact the non-responders. We thereby renounced to track the IP (Internet Protocol) address of each member, for ethical reason too (more discussion below).

Thirdly, the survey was edited mostly by “ESL people” (English as Second Language), with non-perfect grammar and some misspelling (free commentary box: p.123 responders N°11748422; 11773985 f.ex.). It is interesting to see that even if we have gone through 3 different editing steps (our research team with one native English speaking person, anaesthesia department of McGill with several native speaking person and finally 3 directory boards of 3 English-speaking societies) and some misunderstanding or incorrect grammar/vocabulary still persist. Probably, for a future survey, we should ask the help of a professional translator team.

Some topics could have been expanded to better understand individual practice. However, this would have been to the detriment of the user-friendliness. In consequence, we decided to limit the number and the complexity of the questions in order to promote a higher response rate, as a high number of questions and a long survey promote a higher drop-off rate (Burns KE et al., 2008; Schleyer T et al., 2000). For examples, we excluded some topics from the

final analysis, like umbilical lines that are anecdotically inserted in operation rooms or cut-down techniques, which are almost, not used any more nowadays, especially after the venue of 2D US. Of note, the temporal cannulation site has not been included in the questionnaire, although cited in some case reports and still used in few centres (Escribà F., 2015) but has shown a very high burden of complications (cerebral embolization of air or material, reverse cerebral flow during line flushing) that this technique and cannulation site is widely considered not safe enough (Prian GW; 1977) and has been abandoned.

Another disadvantage of the survey is the relative disbalance between societies (number of members and response rate). Although showing a similar rate of answer to other societies (22%), the SPA may have weighed more with a total of 608 complete answers (> 2700 members). In comparison, the CPAS and SARNePI with an answer rate of respectively 21% and 22% had much less weight in the balance (55 members over 259 and 33 over 153). It was in consequence not possible to draw any comparisons and conclusions between North American and European practices, which was one of the secondary endpoints of the survey.

Finally, for ethical reasons, we didn't insert tracking cookies which are a known and efficient technique to track non-responders, in order to specifically address targeted reminder email. However, we felt that this technique was too intrusive and would have precluded participants to take part to the survey. For the same ethical reasons, we left the possibility to skip several questions, few were compulsory to answer in order to continue and finish the questionnaire. Taking some distance, this was an error, as it introduced a bias in the answer rate, not allowing to properly analyze between respondents, even with totally completed questionnaires. On the other hand, AAPOR (American Association for Public Opinion Research; www.aapor.org) states that people have the right not to answer to a question, unless clearly stated in the introductory message.

5.5. Table of comparison between arterial cannulation sites

	Axillary	Brachial	Radial	Ulnar	Femoral	Tibialis posterior	Dorsalis pedis	Cut-down (any site)
Ease of cannulation	Technically difficult; sterility medium; difficult to avoid mobilization	Difficult to stabilize vessel; very mobile	Superficial and easy to palpate; hypotensive or neonates are more difficult to cannulate	Superficial, often larger diameter than radial; may be more mobile	Deeper structures but may be palpated even in deep hypotensive.	Superficial and easily palpated; mobile	Very superficial, may be difficult to palpate	Under direct vision, always successful
Collateral circulation	Yes	No	Dual circulation in most anatomies	Dual circulation in most anatomies	Collateral circulation exists	Collateral circulation exists	Collateral circulation exists	Depending on cannulation site
Neural or adjacent structure injury	Vicinity of brachial plexus nerves; axillary sheath	Brachial plexus (esp. median nerve) anatomically very close in same sheath	of radial nerve close to artery. Risk of carpal tunnel syndrome by	Ulnar nerve (motor and sensory branches) adjacent to artery	peritoneal haemorrhage from high entry site; femoral nerve may	Tibial nerve in the vicinity; same neuro-vascular sheath	Small sensory branches for interdigital zone between toes 1-2	Less risquant for neural structures under direct vision and dissection
Thrombogenicity	Less risk (higher diameter), although shearing risk (movements)	High risk; high shearing forces (elbow movements)	High risk, small lumen	No data found	Large diameter, less risks; however shearing forces by movements	No data found	No data found	No data found
Accuracy of waveform	Reliable waveform due to proximity of aortic arch (even vasoconstricted)	Difference in contour and amplitude	Contour may differe from aortic waveform	Contour may differe from aortic waveform	Reliable and close to aortic waveforms, even after by-pass and hypothermia	No data found	No data found	Depending on cannulation site
Use of ultrasound for cannulation	No data found	No data found	Higher first pass success with US; less hematoma	Higher first pass success with US; less hematoma	Higher first pass success with US (even with beginners)	No data found	No data found	Not applicable

6. CONCLUSION

In conclusion, paediatric arterial cannulation seems to be mostly based on personal preference rather than new evidence. Our survey suggested a uniformity regarding the first choice for arterial cannulation. With regard to the second choices, approaches were not uniform. Similarly, insertion techniques, maintenance regimens, and management of failures and complications vary among responders. Paediatric experience remains pivotal in this practice. Further robust paediatric studies and eventually specific guidelines may be recommended. Research agenda should focus on the implementation and teaching of ultrasound for arterial line access to reduce cannulation attempts, the development of specific arterial catheters that are less thrombogenic (coated, etc.) and the implementation of local standardization protocols (sterility, choice of first site, etc.).

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7. MISCELLANOUS

7.1. Ethics

The Institutional Review Board of the McGill University Health Centre approved the study (Nr 13-451-PED).

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7.3. Disclosures

No disclosures from any involved parties.

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9. ADDENDUM

9.1. Poster Canadian Anesthesia Society – Ottawa 2015

Separate file.

9.2. Poster European Society of Pediatric Anesthesia – Istanbul 2015

Separate file.

9.3. Bromage Research Day – McGill symposium 2014 + 2015

Separate file.

9.4. Raw data

9.4.1. Overall statistics

Survey statistics Report (Time stamp 26 Feb. 2015)

Questionnaires	Count	Completed / Started	Completed / Viewed	Started / Viewed
Sent	**4254**			
Completed	**899**	**76.77%**	54.03%	
Started	1171			70.37%
Viewed	1664			

9.4.2. Questions 1 to 30

Question 1

"What is your current position?"

Staff	972	88.69%
Fellow	31	2.83%
Residents	25	2.28%
Others (specified below)	68	6.20%
Total	**1096**	

"Others position": free comment box

- volunter staff	- retired
- associate professor	- chairman

- Consultant	- Consultant
- NHS consultant	- Consultant
- Consultant anaesthetist	- Consultant
- Registrar	- Consultant
- Consultant	- UK Consultant
- Consultant	- specialist trainee
- consultant	- consultant
- consultant	- consultant
- Consultant	- Consultant
- Consultant Anaesthetist UK	- Consultant
- Consultant	- consultant
- Locum consultant	- Consultant
- Consultant	- Consultant
- Consultant Anaesthetist	- Consultant
- Consultant	- Head
- Consultant	- Consutant
- Consultant	- consultant
- Consultant	- Consultant
- Consultant	- Consultant
- Consultant	- consultant
- Consultant	- uk consultant
- Consultant (UK)	- Private Practice
- Consultant	- chairman
- UK Consultant	- Director Cardiac Anesthesia
- Consultant	- attending in academic center
- Consultant anaesthetist	- Consultant
- Consultant	- CRNA
- consultant	- Consultant UK
- Consultant	- CRNA
- consultant	- Private practice attending

- anesthesiologist	- Soon to retire
- RETIRED	- Trainee

Question 2

"In what kind of institution do you work most of the time?"

Pediatric University Hospital	578	52.59%
University Hospital mixed activity (i.e. ped. and adult)	297	27.02%
General Hospital mixed activity (i.e. ped. and adult)	142	12.92%
Private Clinic	7	0.64%
Others (specified below)	75	6.82%
Total	**1099**	

Other options: Details and free comments to answer "Other"

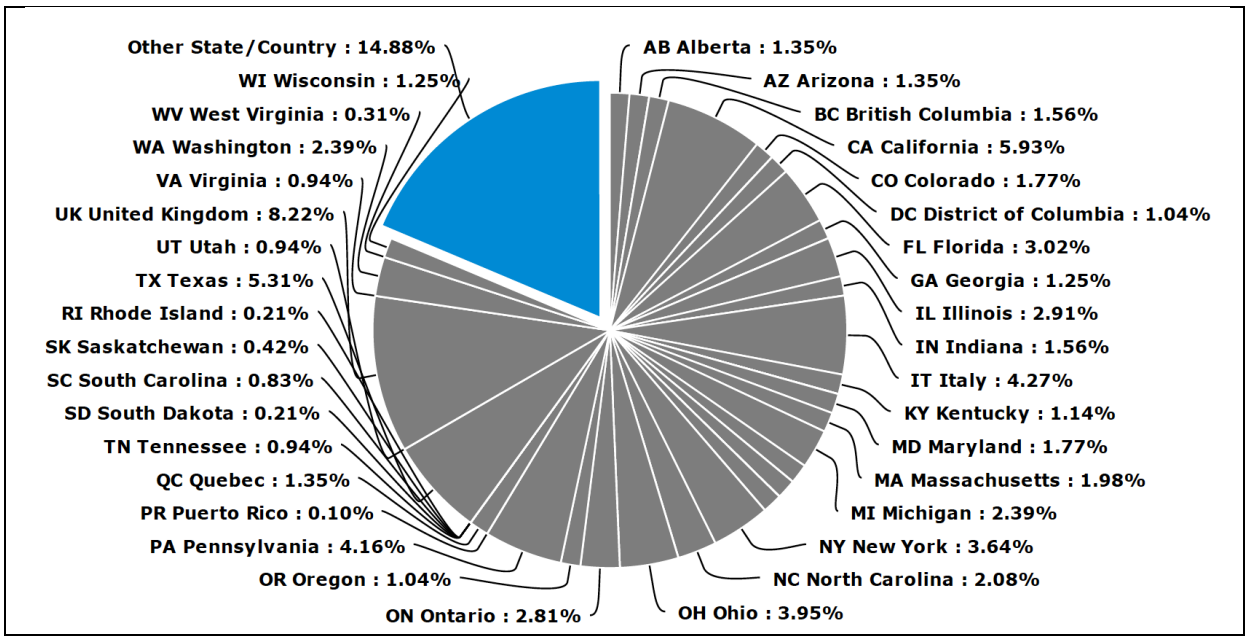
- Pediatric hospital	- pediatric private hospital
- Pediatric Hospital	- Stand alone private practice Peds hospital
- Pediatric Hospital	- pediatric hospital affiliated with a university, but not inside a university hospital, free standing children's hospital
- Pediatric Hospital	- University Hosp with mixed activity, plus private practice all pediatric hospital
- Pediatric Hospital	- Stand alone independent children's hospital.
- Adult only	- Free standing pediatric hosptial
- Specialist Cardiothoracic Tertiary Referral Hospital	- Private Children's Hospital
- Mixed tertiary orthopaedic	- peds non university
- Pediatric nonUniversity Hospital	- Private Pediatric Hospital
- district general hospital, UK	- Pediatric community hospital
- Pediatric Hospital	- free standing pediatric hospital
- and burns	- Private Childrens hospital
- Private children's hospital	- Pediatric hospital as hospital employee
- Private pediatric hospital	- private pediatric hospital associated with an University
- Freestanding pediatric hospital	- Pediatric private hospital
- Pediatric Hospital - non university	- Peditric Hospital affiliated to University
- Private pediatric hospital	
- Pediatric outpatient facility	

- Private pediatric hospital
- Pediatric hospital, not university affiliated
- Pediatric Private Hospital
- Military, adult and pediatric
- Ambulatory Care Center
- Private pediatric hospital
- private peds only practice at a tertiary referral peds hospital, with some teaching responsibilites, but not an "academic"/university hospital
- Pvt. Children's Hospital
- free-standing children's hospital
- Children's Hospital within an Adult Hospital
- Pediatric free standing hospital
- Private pediatric hospital
- Pediatric Hospital, University affiliation
- private pediatric hospital
- free standing pediatric hospital
- private pediatric hospital
- children;s hospital
- Private pediatric hospital
- Pediatric private hospital
- non university childrens hospital

- Private free-standing children's
- Freestanding pediatric hospital
- Pediatric Hospital, non university
- shriners hosptial
- free standing pediatric hospital
- Exclusive pediatric practice at multiple private hospitals.
- Shriners Hospital
- Pediatric private hospital Phoenix Chidrens
- Private Community Pediatric Hospital
- Private Childrens Hospital
- private pediatric hospital
- Shriners Hospital: a non-university pediatric hospital
- Pediatric outpatient surgical clinic
- Military Hospital mixed peds and adult
- Pvt Children's Hospital
- I split my time equally between a Pediatric University Hospital and a University Hospital
- Pediatric private hospital
- non-profit pediatric hospital
- Pediatric Private Hospital
- Private Pediatric Hospital

Question 3

“Please provide the Province / State of your medical activity?”



1

Descriptive data		
UNITED STATES AMERICA	619	64.41%
CANADA	79	8.11%
UNITED KINGDOM	79 (+ 55)	8.22% (13.94%)
ITALY	41 (+ 6)	4.27% (4.89%)
Others (specified below)	143 (- 61)	14.88% (8.53%)
Total	**961**	
Others		
Italy	+ 6	
UK	+ 55	
Singapore	1	
Brazil	2	
Netherlands	4	
Poland	1	
Belgium	2	
Australia	4	
Slovakia	1	
Austria	2	
Argentina	1	
Germany	1	
Colombia	3	
Chile	2	
Mexico	1	
Hungary	1	
Thailand	1	
Switzerland	3	

India	1	
New Zealand	2	
Irak	1	
Japan	1	
Not specified	47	

Question 4

"How often do you practice pediatric anesthesia in the operating room per month?"

< 4 days per month (one day per week)	64	5.85%
4-8 days per month (two days per week)	123	11.24%
8-12 days per month (three days per week)	147	13.44%
12-16 days per month (four days per week)	184	16.82%
> 16 days per month (everyday practice)	576	52.65%
Total	**1094**	

Question 5

"How many years of experience do you have in paediatric anaesthesia?"

0-5 years	262	23.84%
6-10 years	203	18.47%
11-15 years	149	13.56%
16-20 years	127	11.56%
>20 years	358	32.58%
Total	**1099**	

Question 6

"How often do you place arterial lines in children?"

Never	12	1.09%
Very occasionally (1-5 per year)	143	12.95%
Less than one per month (6-12 per year)	189	17.12%
Between one and two per month (13-24 per year)	221	20.02%
More than two per month but less than one per working day (25-42 per year)	299	27.08%
More than one per week (more than 42 per year)	240	21.74%
Total	**1104**	

Question 7

“Do you have local written guidelines for arterial cannulation (i.e. technique, dressing, sterile precautions)?

No	804	75.35%
Yes (if possible, please specifiy)	263	24.65%
Total	**1067**	

Other options: Details and free comments to answer “Yes” question 7

- sterile precaution
- written protocol on technique
- hospital guidelines
- It is a guidance for arterial cannulation for adult and paediatric on dressing and sterile precaution.
- For Adults but not for Children
- Yes - re skin prep otherwise no
- sterile, 2% chlorhexidine prep
- Generic vascular access guidelines for line insertion in terms of sterility
- sterile precautions
- Generic procedure format on computerised system: Allen's test, asepsis, site, gauge of needle, number of attempts/difficulty, dressing, any complications, attending signs off procedure
- Nursing Care
- Sterile prep/drape/gloves. No gown required
- Arterial line pack, plus sticker in the patients' notes which is countersigned by assistant to confirm removal of guide wire (if used..)
- Radial, ulnar, tibial posterior, femoral in desperate situations, US if available, transillumination in premies and small neonates, sterile precautions, no dressing
- gown and gloves
- there are written guidelines on PICU
- All of the above
- Basic equipment and technique guidelines i.e. how to fix in place etc
- Sterile precaution
- Not specifically paediatric
- cannula site, asepsis and flush/infusion set up outlined in guidance- not specifics on technique
- Avoid brachial, clear dressing, sterile technique, appropriate clinical area

- as per vascular access - so chlorprep (except for neonates and IV3000 dressings
- PICU guidelines
- cleaning if inserted / flow driven trough
- Available for adults & CATS guidelines are readily available for children
- chloroprep, sterile dressing aseptic tech
- Not technique specific but chlorhexidine sterile prep and drape and surgical gloves
- sterile prep
- We follow the CDC recommendations that require sterile prep and drape, hand washing, sterile gloves, hat and mask. We do not gown or use a full body drape.
- hospital guidelines for prep and dressing
- not technique, but guidelines for dressing and sterile precautions
- sterile technique: sterile prep/drape/placement
- chlorhexidine, drapes, sterile gloves
- sterile prep, setup and gloves
- maximal barrier precautions with no difference between CVL or arterial lines. A percutaneous long term (>2 days) line is a line.
- Sterile precautions, dressing, and labeling
- Sterile
- Sterile drape , sterile gloves, if ultrasound used it is draped sterility, tegaderm, and arterial line labeling.
- sterile prep and drape similar to CVL placement
- sterile dressing with biopatch
- Sterile technique, sterile dressing and Ultrasound guided
- sterile precautions
- biopatch used
- sterile precautions
- Dressing requirements
- Asseptic technique
- Sterile prep, gloves and drapes
- Guidelines published
- <10 kg, US guided sterile prep, sterile seldinger technique, gown, gloves, cap, sterile dressing

- seldinger technique, sterile conditions
- Use of Chlorhex, clear dressing, mark date of insertion.
- Sterile technique to be used
- Sterile technique with full drape, sutured in
- sterile precaution
- not sure if written but we use sterile technique
- Sterile technique but not full barrier precautions unless femoral.
- hospital protocols for dressings and care
- probably, don't recall seeing them
- Biopatch and tegaderm
- "Sterile technique guidelines: chlorhexidene prep, sterile gloves
- Sterile precautions, biopatch, tegaderm dressing
- Tech, dressing, sterile precaution, indication, assessment of perfusion preprocedure
- each staff sends out plan night before. I do all my A-lines with full sterile precautions ans]d ultrasound guided and wire assisted
- Anesthesia Department protocol on Aline Placement
- hospital policy
- special dressing and sterile precautions
- written protocol
- P/P
- Sterile precaution (scrub,gown, mask, gloves)
- chlor hex sterile prep with drapes, clear sterile dressing with steristrips and tape to secure
- tape thumb and hand apropriately on arm board, chlorhex prep, sterile drape, angiocaths and seldinger wires, 19g needle to puncture skin, steristrips, mastisol, chlorhexidine disk, tegaderm
- sterile precautions
- Protocol for hand washing, sterile gloves, chlorohexidine skin prep, palpation of pulse vs US, mastisol, steri-strips or suture, tegaderm
- prepped, draped, sterile gloves
- Chloroprep, sterile drape and gloves
- Standardized sterile precaution, material, and technique used
- The hospital has infection control guidelines, these mostly get ignores except for the

cardiac rooms or for a patient in whom the line will stay more than 24 hours
- It is a written policy
- Consent, Timeout, sterile prepped and draped, gown, gloves mask,
- sterile prep and drape
- Wash hands before donning sterile gloves. Use sterile drapes. Cannulation technique per individual practitioner and varies with patient. Clear sterile dressing.
- vascular access protocol
- Sterile technique and dressing
- Hospital policy
- Sterile technique and dressing recommendations
- guidelines indicating proper dressing, physisian outfit, sterile precautions and positioning
- Sterile prep, US
- Universal precaution, dressing and site marking
- sterile precautions/dressing--much same as central line
- biopatch application prior to dressing catheter
- Sterile prep, drape, precautions, how to secure, specific catheters, how to secure and physician taking specific sterile precautions. All institutional guidelines present and in place to be used everytime.
- Hospital protocol
- Sterile precaution
- Sterile prep, drape, extension piece handed to field sterilely
- full sterile set up special canulae wires
- Sterile bundle
- ID recommends gown and full body drape. we do not subscribe to that in OR
- ID recommends gown and full body drape. We do not do this in OR. No OR guidelines written that I know of. We use sterile gloves, mask, local drapes, and prep.
- sterile technique, suture or tape to secure
- stérile technique: gloves, mask, hat, prep, dressing
- sterile precautions
- technique, dressing, sterile vad precautions (includes scrub, draping gloves etc
- sterile prep, drape and technique
- sterile precautions and dressing yes, technique no

- aseptic technique including chlorhexidine prep, drape, optional taping vs sewing at personal preference, clear occlusive dressing (ex tegaderm, sorbaview, etc.)
- guidelines for dressing
- Dressing, securing and sterile precautions
- sterile technique, prep, timeout
- sterile precautions
- Chloraprep skin prep
- sterile prep and drape
- sterile gloves, chlorhexidine, mask
- on hon hospital infonet
- Specific arterial line bundle and technique
- Site preference then sterile technique (antiseptic solution, gown, glove, drape etc. Handling and use policy.
- sterile precautions, technique
- Guidelines on size/location; protocols on sterile precautions and dressing.
- we have a vascular access policy in the hospital regarding sterile precautions and dressing
- Sterile precautions and dressing. No guidelines for technique
- Full sterile technique
- policy and procedure manual
- prep only
- addressing sterile approach
- sterile precautions "bundle", time out, correct site,
- gown gloves (no one does it)
- Policy and procedure manual
- Guidelines for securing with antibiotic dressing
- Mandatory check list
- all of the above: sterile prep, drape, full gown/glove
- use of total sterile barrier technique, bio-patch, clear dressing
- chloroprep and sterile gloves
- Gloves chloraprep

- not written but understood
- sterile gloves, sterile prep and drape
- chlorhex prep, sterile drape, sterile gloves, angiocath, seldinger technique, chlorhexidine disk, steristrips, tegaderm
- departmnet policy manual
- sterile conditions, marked with arterial line sticker
- checklist
- Prep and biopatch
- Sterile gloves,sterile towels, CHD prep
- sterile prep and dressing
- chlorhexidine dressing if over 1 yr
- protocol for sterile field and format for documentation of technique, quality of waveform etc.
- We follow cdc guidelines for sterile technique
- vascular access protocol
- Protocol for gloves, sterile prep and field, etc
- Sterile protocol
- sterile procedure
- prep w chorohexidine, sterile precaution
- too long
- Sterile precaution on blood withdrawal
- nursing care and procedure preparation
- We have stressed use of sterile technique, the approach is user dependent
- ICU nursing protocol
- Sterile technique, prep (chloroprep versus iodine depending on age), sterile drape and gauze, sterile needles and kit. Sterile gloves.
- Guidelines for sterile placement.
- sterile precautions, sterile technique
- we have a premade kit with drapes and most of us use USG
- chlorhexidine prep, sterile drape. sterile gloves. suture or stat-loc, biopatch and tegaderm
- dressing must be clear, hub of catheter padded, chlorhexidine prep

- strict sterile procedure

Question 8

"What medical device do you usually prefer for arterial cannulation in pediatric patients?"

Venous cannula (i.e. Jelco, etc.)	830	77.57%
Specific arterial cannula (please specify)	240	22.43%
Total	1070	

Other options: free comments to answer "Specific arterial cannula"

- arrow
- arrow 22-24 g
- seldinger tecnique Vygon
- plastimed, arrow 2-3 Fr
- vigon or arrow
- Arrow/ Vygon
- BD arterial cannula
- Arrow
- Arrow
- Arrow
- seldicath
- seldicath-plastimed
- seldicath plastimed
- Arrow
- Abbocath
- Vygon
- Arrow
- Use both insyte (similar to your jelco)and specific Cook or Vygon arterial devices
- Arrow Seldinger 22G
- vygon

- Leadercath. Will also use hello if not in for long
- Vygon 115090
- Abbocath
- Leadercath 20G, Arrow 24G, occasional Careflow 22G. Otherwise Insyte 22/24G in radial
- Abbocath
- Vygon
- Insyte-A, Arrows
- Insyte_A, Arrwos
- Vygon
- insyte or cook
- Cook or vygon
- Arrow arterial line
- I use different kinds but usually prefer arrow art lines
- Abbocath
- Arrow
- Various depending on size of patient / vessel
- abbocath
- Cook cannulas for long term Angiocath or Jelco for short term
- Vygon 20g
- Abocath
- Abbocath
- Insyte 22G, 24G
- abbocath
- InSyte
- Arrow
- Vygon or flowswitch
- Ledercath
- gelco for smaller infants, ledercath otherwise

- non ported cannula eg abbocath/insyte
- Ledercath
- abocath
- Beckton Dickenson Arterial Canula
- Floswitch, Vygon,
- Arrow
- Abbocaths
- Cook
- depends on site of insertion
- Arrow
- arrow
- Arrow seldinger, 22g 5cm
- vygon flow switch if child is big enough otherwise jelco
- arrow (but using jelco for initial puncture)
- Arrow 5cm 22G arterial line
- both Jelco and seldniger lines
- Abbocath
- abbocath
- Abercath
- Arrow Arterial Set 24G
- in newborn venous cannula; there is no specific material available
- abucath
- ledercath
- 22 or 20g arrow
- Cook catheter for long Angiocath for short term
- Ledercath
- switch cannula
- Arrow 5cm or 8cm 22g kit

- switch cannula
- Cook caths; switch over even if use Jelco to get in
- arrow or special kit
- Cook 2.5 Fr 5cm
- Not sure
- Braun venous cannula for 22g but Arrow kit for older. Cook 2.5 F 2.5cm for neonatal radial artery and cook 2.5F or 3F longer catheters for children getting femoral arterial lines
- Arrow cath
- cook
- 2.5Fr, 2.5 cm caatheters and larger sizes
- cook 2.5F single lumen catheters
- arrow kit
- depends on age of child: jelco or similar for young child, Arrow kit or Cook catheter kit for older child
- Cook arteial catheter kits
- both, based on age of child: venous cannula for younger child unless in femoral artery then use Cook catheter kit, Arrow or Cook catheter for older child
- arrow or cook
- arrow
- Arrow, I think.
- arrow kit
- Arrow catheter 20 or 22g, and jelco 24g
- 2.5 for cook catheter
- Arrow
- arrow
- Cook arterial line kit
- Arrow
- Cook kits
- cook catheter
- depends on location
- Arrow for 20 G and above, Terumo for smaller

- 2.5 FR2.5-5cm Cook
- Abbo cath 22gauge venous cannula
- 24, 22, 20 G Insite depending on size of child
- angiocath (PIV cannula to access, vein, then over-wire exchange to 2.5Fr arterial cannula
- Cook arterial cannulas
- Cook arterial lines 2.5 Fr and 3 Fr catheters
- 2.5 and 5 cm catheter kits
- Arrow catheters, using insyte autogaurd access, arrow cath over guidewire
- I use IV cath or Arrow kit
- Harrow
- Cook
- arrow
- For babies Cook 2.5 F, 2.5 cm catheter. For older children, Arrow arterial cannulas with wire, either 22 or 20 G
- aerocath
- depends on siz of patient
- arrow catheter
- Cook 2.5 g
- Pediatric Arrow catheter
- Cook
- Arrow
- 2.5 French 2.5 cm radial in babies, 22 g or 20 g arrows in larger kids
- Cook
- Both Jelco and Cook catheters I believe
- Cook
- Cook
- Cannula and a variety of Cook products 2.5 F 3F
- Arrow
- Arrow and Cook

- both venous cannula and arterial line kit with wire
- Cook
- Jelco(for younger pts) or arrow cath for older pts
- Cook catheter kit
- Arrow 22 G for children greater than 3 kg, 20 G for children greater than 5 years
- Arrow arterial catheterization kit
- Cannulate with venous catheter then exchange over wire with arterial catheter
- "non-safety" canulae
- Cook kit
- 2.5F Cook
- combination - jelco and then rewire to cook arterial line
- cook wire and either their cannula or regular venous catheter
- Arrow
- Arrow
- Arrow
- cook medical 2.5 or 3FR
- Cook 2.5 Fr2.5 cm or 2.5Fr5cm catheters designed for arterial cannulation
- jelco transitioned to cook arterial line
- arrow kit 22ga
- Vygon 115.09
- Cook
- Arrow single lumen catheter using Seldinger technique with initial arterial puncture with a venous cannula
- terumo
- Cook catheter
- Dependent on patient size: 2.5Fr x 2.5cm Cook cath for children <~30kg, then 20g short angiocath for larger children.
- Cook 2.5Fr x 5 cm or x 2.5 cm
- arrow brand, french sizing catheters
- arrow kit

- start with a 24 g Jelco and wire to a Cook arterial catheter
- Cook Medical 2.5Fr 2.5 cm or 5 cm, 3 Ft 5cm available
- Cook kit using Arrow catheter or Insyte
- cook 2.5fr 2 cm
- Jelco 22g venous cannula; Needle in Cook 2.5 french kit; Argon needle; Arrow needle (for adolescents)
- Cook 2.5 Fr 2.5 cm catheter set that includes chloraprep, dressing, flush
- arrow 22g or 20g kit wire in housing
- either jelco cannula or arrow radial artery catheterization set - 20g
- arrow catheter
- Cook Arterial Cannula
- Pediatric Kit for Aline
- site specific. Insyte arterial, Abucath of Arrow femoral, Leadercath older patient
- Cook
- 2.5 x 2.5
- 22 or 24 g angiocath
- Arrow cath and other kits
- Radial artery kit, Arrow
- arrow
- Arrow and Cook arterial cannulas
- Arrow set
- arrow
- Arrow cath. 20G or 22G
- Cook
- Arrow
- Arrow
- Arrow
- Use venous canula to get access then 2.5 f 2.5 or 5 cm
- arrow

- Arrow arterial catheter
- cook kit 2.5F x 2.5, or 2.5 F x 5 cm
- #22G
- Bd
- depends on age/size (venous cnnula, 20g arterial catheter, or 2.5F/2cm catheter.
- B braun
- Arrow
- arrow kits
- Arrow
- 2.5 fr 2.5 cm cook
- Cook with greater than 6 yo...venous cannula, angiocath for younger
- wire changed after venous cannula
- Varies according to age and size
- arrow
- baxter
- Cook
- Jelco for radial and cook or arrow for femoral
- Rarely do I use an arterial cannula kit. Usually, our group uses venous catheters.
- Arrow catheter
- Arrow as a backup
- Use venous cannula for initial puncture and access into artery. Then wire is used through the cannuala and an arterial cannuala is inserted over the wire. Kit made by cook medical
- Angiocaths
- Arrow
- Arrow or Cook
- cook
- Cook 2.5fr 3.5cm single lumen catheter
- varies with site, venous cannula or not
- Arrow Arterial Line Kit

- Will use venous cannula to obtain flash, wire the cannula, and then place specific arterial cannula over the wire.
- venous catheters below 6 yo; Arrows above 6 yo
- jelco

Question 9

"How often do you use the following sites as first choices for arterial cannulation? (5 stars 0 most of the time; 1 star = least of time)

- Ask / perform a cut-down (any site)
- Axillar
- Brachial
- Dorsalis pedis
- Femoral
- Radial
- Tibialis posterior
- Umbilical artery (when appropriate)
- Ulnar

1. Ask / perform a cut-down (any site)

1	**555**	**88.94%**
2	44	7.05%
3	15	2.40%
4	4	0.64%
5	6	0.96%
Total	**624**	

2. Axillar

1	**534**	**78.99%**
2	97	14.35%
3	40	5.92%
4	3	0.44%
5	2	0.30%
Total	**676**	

3. Brachial

1	**492**	**69.30%**
2	121	17.04%
3	71	10.00%
4	21	2.96%
5	5	0.70%

Total	**710**	

4. Dorsalis pedis

1	**278**	**36.58%**
2	251	33.03%
3	175	23.03%
4	49	6.45%
5	7	0.92%
Total	**760**	

5. Femoral

1	115	13.67%
2	200	23.78%
3	**288**	**34.24%**
4	175	20.18%
5	63	7.49%
Total	**841**	

6. Radial

1	14	1.46%
2	6	0.62%
3	17	1.77%
4	56	5.83%
5	**868**	**90.32%**
Total	**961**	

7. Tibialis posterior

1	**310**	**42.76%**
2	193	26.62%
3	154	21.42%
4	57	7.86%
5	11	1.52%
Total	**725**	

8. Umbilical artery (when appropriate)

1	**420**	**64.22%**
2	99	15.14%
3	59	9.02%
4	38	5.81%
5	38	5.81%
Total	**654**	

9. Ulnar

1	**353**	**47.64%**
2	161	21.73%
3	131	17.68%
4	76	10.26%
5	20	2.70%
Total		

<u>Question 10 ("baby scenario 1")</u>

"Assuming that you need to put an arterial line in a full term 1 month old baby with all arterial sites equally available (no specific concerns related to surgery or patient's disease), please mark your preferred sites of cannulation (up to five):

- Ask/perform a cut-down (any site)
- Axillar
- Brachial
- Dorsalis pedis
- Femoral
- Radial
- Tibialis posterior
- Ulnar

Ask/perform a cut-down (any site)

First choice	5	1.05%
Second choice	8	1.68%
Third choice	35	7.34%
Fourth choice	76	15.93%
Fifth choice	169	35.43%
N/A	**184**	**38.57%**
Total	**477**	

Axillar

First choice	2	0.44%
Second choice	9	1.97%
Third choice	56	12.23%
Fourth choice	88	19.21%
Fifth choice	128	27.95%
N/A	**175**	**38.21%**
Total	**458**	

Brachial

First choice	7	1.40%

Second choice	54	10.78%
Third choice	90	17.64%
Fourth choice	99	19.76%
Fifth choice	107	21.36%
N/A	**144**	**28.74%**
Total	**501**	

Dorsalis pedis

First choice	4	0.68%
Second choice	**142**	**24.07%**
Third choice	195	33.05%
Fourth choice	122	20.68%
Fifth choice	72	12.02%
N/A	55	9.32%
Total	**590**	

Femoral

First choice	71	8.22%
Second choice	**321**	**37.15%**
Third choice	256	29.63%
Fourth choice	143	16.55%
Fifth choice	63	7.29%
N/A	10	1.16%
Total	**864**	

Radial

First choice	**879**	**92.62%**
Second choice	59	6.22%
Third choice	2	0.21%
Fourth choice	3	0.32%
Fifth choice	2	0.21%
N/A	4	0.42%
Total	**949**	

Tibialis posterior

First choice	7	1.18%
Second choice	159	26.77%
Third choice	**162**	**27.27%**
Fourth choice	113	19.02%
Fifth choice	68	11.45%
N/A	85	14.31%

Total	**594**	

Ulnar

First choice	10	1.75%
Second choice	**205**	**24.07%**
Third choice	94	16.49%
Fourth choice	74	12.98%
Fifth choice	80	14.04%
N/A	107	18.77%
Total	**570**	

<u>Question 11 ("baby scenario 2")</u>

"In case you put a radial arterial line in a full term 1 month old baby, what size would you choose?"

26 Gauge iv catheter (i.e. Jelco, etc.)	12	1.24%
24 Gauge iv catheter (i.e. Jelco, etc.)	**672**	**69.64%**
22 Gauge iv catheter (i.e. Jelco, etc.)	199	20.62%
Specific arterial cannula (please specifiy)	82	8.50%
Total	**965**	

Other options: free comments to answer "Specific arterial cannula"

- 2 french 2 cm	- Arrow 5cm 22G arterial line
- plastimed 2 Fr x 2 cm	- NA
- 22 arrow	- 22g arrow
- Arrow 24 G	- 24g angiocath
- Arrow 22g arterial cannula	- 24 gauge Jelco and switch to cook 2.5X2.5 over wire
- Arrow	- cook 2.5 fr x 2.5 cm kit
- 22g abbocath	- 2.5 fr 2.5 cm cook
- Cook	- 2.5Fr, 2.5 cm arterial canula
- Insyte 24G	- 2.5 Fr 2.5 cm Cook catheter
- 24g Arrow 2.5 cm line	- 2.5 Fr
- abocath 24G	- 2.5f
- 2.5Fr	- Cook 2.5 fr
- Arrow	- 2.5 French

- 2.5 french, 2.5 cm
- 2.5fr/2.5 cm cook
- 2.5 fr x 2.5 cm cook catheter
- 2.5Fr 2.5cm
- I may rewire at time of insertion with 22 G
- Cook 2.5F 2.5cm arterial catheter
- 2.5 French
- 2.5 fr
- 2.5 Fr 2.5 cm arrow art line
- Cook 2.5F, 2.5cm
- 2.5 French, 2.5 cm silastic catheter
- 2.5 Fr
- 2.5F, 2.5cm
- 2.5 cm2.5Fr Cook
- 2.5 f
- 2.5F 2.5 cm
- Cook 2.5F
- 2.5F 3 cm
- 2.5 French 3 cm cook
- 22 gauge Cook kit
- 2.5F
- cook 2.5cm, 2.5 fr
- 2.5 Fr 2.5 cm
- 22 ga. Arrow
- Cook 2.5Fr2.5cm
- 2.5 french cook
- 2.5 Fr
- arrow pediatric arterial kit

- 2.5F 2.5cm Cook
- 2.5 fr, 2.5 cm
- 2.5 Fr x 2.5 cm Cook
- 2.5 Fr x 2.5 cm Cook
- 2.5Fr, 2.5cm
- start with a24g Jelco wired to a 2.5Fr arterial Cook catheter
- 2.5 french 2.5 cm
- 2.5 Fr arterial catheter
- 2.5 Fr, 4 cm
- Arrow 24G 2.5 or 5cm
- 2.5 x2.5
- 2.5 fr 1inch cook
- 2.5 Fr arterial line 2.5 cm
- 2.5 Fr 2.5cm Arrow cath
- Arrow 22G
- 2.5 french
- Then 2.5 french
- arrow 22
- 22 ga Arrow arterial catheter
- 2.5 French catheter
- Arrow 24G 2,5 cm
- 22
- 2.5 fr. Cook catheter
- specifically #22 Angiocath (is an iv catheter)
- 2.5 french, 3 cm length
- 2.5F
- 2.5 fr 3.5cm cook catheter
- 2.5 French

1 1

2

Question 12 ("baby scenario 3")

"In case you put a femoral arterial line in a full term 1 month old baby, what size of catheter would you use?

24 Gauge iv catheter (i.e. Jelco, etc.)	44	4.56%
22 Gauge iv catheter (i.e. Jelco, etc.)	280	29.02%
2.5 Fr 5 cm	366	37.93%
2.5 Fr 8cm	42	4.35%
3 Fr 5 cm	143	14.82%
4 Fr 8 cm	21	2.18%
Other (please specifiy)	69	7.15%
Total	965	

Other options: free comments to answer "Specific arterial cannula"

- plastimed 2 Fr x 4 cm
- 22 G 5 cm Vygon
- 22G or 24G 5cm arterial line
- Arrow 24 G
- Arrow 22G Seldinger
- Arrow 24G 5cm
- 4fr 5cm
- 22G 4cm
- Arrow 22G
- 22 G arrow
- 22 G arrow art line
- 22g abbocath
- 22g silastic single lumen
- 24g Arrow 5 cm line
- 22G vygon
- unsure
- 20g 8cm
- either 22g gelco or 20G ledercath
- Arrow 5cm 22G arterial line
- 22G Vygon Leadercath, for extra length
- NA
- 22g arrow
- available 3 Fr 6 cm or 2 Fr 3 cm
- 20G angiocath
- 22g long catheter
- Would not perform
- 3 Fr 5 cm (we do not have a 2.5 Fr 5 cm which is what I WOULD chose)
- I would not do this
- I ferquently use 3F 8 cm line as less likely to become nonfunctional in this position
- infrequently done
- 2.5 FR 2.5 cm
- Don't know
- 20 g 5 cm Cook
- 22G arrow catheter
- 24 ga 8 cm arrow catheter
- Or 2.5 Fr 2.5 cm
- 2.5 Fr 4 cm cook
- usually ask surgeons to place

- 2.5 Fr 3 cm
- not sure
- surgeon place most of time
- 3 French 5 cm
- Arrow 22g 5cm Arterial Line
- 22G 7 cm
- NA don't do it
- 22g x 4cm Vygon leaderflex
- 3 Fr 8 cm
- Arrow Radial Artery Catherter 22G
- Arrow 24g 5 cm
- dont know
- 22G 8 cm catheter
- Appropriate kit for size
- 20 g
- not sure

- 20 g
- 22g arrow 5cm
- Wouldn't.
- Arrow 24 G 5 cm
- 2.5 Fr 3cm
- 3 fr 8 cm
- long #22
- arrow #22 5cm, but access with 22 Angiocath
- Dont do it
- 22 G Arrow
- 2.5fr 5cm cook catheter
- have never done this
- would not use
- 2.5 Fr 2.5 cm
- 2.5 Fr 2.5 cm

1

1
2
3 **Question 13**
4
5 **"When you decide to change site because unsuccessful at the primary site (arterial**
6 **supply not compromised after cannulation attempts), what do you do?(please drag by**
7 **decreasing level of preference: TOP (1) = first/best choice - BOTTOM (5) = last/least**
8 **choice)"**

Staying at the same level, same limb (i.e., radial vs ulnar or posterior tibial vs dorsalis pedis)									
1		2		3		**4**		5	
202	21.72%	156	16.77%	228	24.52%	**252**	**27.10%**	92	9.89%
Changing level, same limb (i.e., radial vs brachial or axillar)									
1		2		3		**4**		5	
76	8.17%	181	19.46%	270	29.03%	**314**	**33.76%**	89	9.57%
Changing to controlateral limb (any site)									
1		2		3		4		5	
631	**67.85%**	182	19.57%	110	11.83%	7	0.75%	0	0.00%

Changing from upper limb to lower (or vice-versa)									
1		**2**		3		4		5	
18	1.94%	**410**	**44.09%**	256	27.53%	242	26.02%	4	0.43%
Prepare for cut down (any site)									
1		2		3		4		**5**	
3	0.32%	1	0.11%	66	7.10%	115	12.37%	**745**	**80.11%**

Question 14

"In cooperative patients and prior to arterial puncturing at radial/ulnar level, do you assess collateral perfusion (most of the time)? »

Classical Allen's test (clenching the hand, THEN digital compression of both ulnar and radial arteries, THEN opening the hand and release the pressure on ulnar artery, measure the reperfusion time)	65	6.85%
Modified Allen's test (digital compression of both ulnar and radial arteries, THEN clenching and opening the hand, THEN release the pressure on ulnar artery followed by the radial artery, measure the reperfusion time)	86	9.06%
Enhanced modified Allen's test (i.e., acoustic and/or colour Doppler to evaluate reperfusion adequacy, plethysmography, saturometer during classic Allen's test)	41	4.32%
No testing	**708**	**74.60%**
Other (please specify)	49	5.61%
Total	**949**	

Other options: free comments to answer "Other tests to assess collateral perfusion"

- I never use ulnar
- Allen's test AND palpation of limb vessels
- do not use ulna if had to would use colour flow doppler
- check that both ulnar and radial pulses are palpable
- ultrasound to check flow
- often assess vessel size with ultrasound and check pulsation
- use US
- always look at ultrasound flow
- I don't do ulnars

- I do not do ulnar cannulate in at my institution. So if I do not get radial I do not move ulnar. Since. It is not a Peds only hopsital.
- Ultrasound for patency, I do not place ulnar arterial lines
- All arterial lines in our pediatric CV practice are placed under u/s guidance and an u/s guided enhanced Allen's test is performed.
- Only if I have missed the radial artery, and am going to attempt an ulnar stick, I will make sure that there is still pulsatile flow (palpation or ultrasound) in the radial before attempting ulnar
- Feel pulses

- pulse ox to verify perfusion with artery (ex radial) occluded
- make sure good pulse on both sides
- I check both pulses if necessary with ultrasound
- ultrasound
- only if puncturing 2nd vessel in wrist ,then classic-otherwise no testing
- ultrasound look for perforators
- Do testing a minority of the time, after anesthetized
- ultrasound visualization
- feel for presence of both pulses
- feel for both pulses present
- Infrequent
- just feel pulses and/or ultrasound
- Ultrasound identification of arterial pulsation
- Check with ultrasound patency of vessel
- ultrasound
- patient history only
- look at ultrasound image
- ultrasound vis of ulnar/radial art

- I check with the ultrasound
- look with ultrasound machine
- view both sides with ultrasound
- ULTRA SOUND
- always placed asleep
- ultrasound
- Compression with pulse oximetry
- USG to look at the flow
- When the pulse is not palpable, ultrasound the ulnar and Radial arteries. If any issues than look at an alternative site
- palpate ulnar pulse prior to insertion of radial arterial line
- US to check flow in other vessels
- use ultrasound
- checking presence of ulnar pulse
- Look at ultrasound doppler flow
- Feel that radial and ulnar pulses present
- Feel that both radial and ulnar pulses palpable

Question 15

“What technique do you use most of the time to cannulate the artery in an infant (percutaneous approach)? »

"Going through the posterior wall and draw back until backflow of blood is seen", then thread OVER a wire (Seldinger technique)	**321**	**33.68%**
"Going through the posterior wall and draw back until backflow of blood is seen", then thread WITHOUT a wire	147	15.42%
" Puncturing and threading the cannula (without hitting the posterior wall)" OVER a wire (Seldinger technique)	118	12.38%
" Puncturing and threading the cannula (without hitting the posterior wall)" WITHOUT a wire	318	33.37%

I do not use a specific technique	24	2.52%
Other (please specify)	25	2.62%
Total	**953**	

Other options: free comments to answer “Other techniques to cannulate the artery”

- Ultrasound guided fourth technique
- Depends on circumstances
- Direct vision under US guidance (realtime). Enter the vessel until back flow seen, flatten off, advance a little, withdraw needle, advance cannula under direct US vision up the vessel (no post wall perforation)
- D
- Ultrasound guided puncturing and threading without puncturing back wall
- Ultrasound
- radial: puncture and thread canula 50:50 without hitting posterior wall vs through posterior wall then threading in. Femoral: puncturing and thread ove wire, without puncturing posterior wall
- any of the above depending on the vessel. usually try to thread without a wire, but have a 'babywire' handy in case of difficulty
- I direct cannulate with ultrasound real time
- I always have wire in field. If I cannot advance cannula I go through wall and draw back and thread over wire
- I do use perc approach in infant
- Ultrasound
- Ultrasound guided in plane
- transduce
- try to directly cannulate, but inevitably transfix fairly frequently. Use spring loaded guide wire to rescue on way back
- ultrasound
- Ultrasound
- 2D ultrasound guided
- Ultrasound, avoiding through and through, wire if needed
- ULTRA SOUND
- Using ultrasound
- ultrasound, trough posterior wall or simple puncture, always over a wire
- ultrasound puncture thread without post wall, no wire

Question 16

"To locate the artery, what technique do you use most of the time?"

Anatomical landmarks and/or palpation	**712**	**73.78%**
Doppler Ultrasound (acoustic signal) before the puncture (preprocedural scan only)	17	1.76%
Puncture assisted with Doppler Ultrasound (changes in acoustic signal during arterial puncturing; real time scan)	12	1.24%
2D Ultrasound (anatomy displayed on screen in 2 dimensions) before the puncture (preprocedural scan only)	21	2.18%
Puncture assisted with 2D Ultrasound (visual real time needle tracking, in plane or out of plane)	189	19.59%
Other (please specifiy)	14	1.45%
Total	**965**	

Other options: free comments to answer "Other techniques to locate the artery"

- Transillumination
- radial, by palpation, femoral using real time ultrasound
- Real time US for femorol.50:50 real time US or palpation for radial
- red light transillumination
- Try US but limited at radial in infants due to size.
- cutdown - direct visualization
- Palpating for radial arteries. If unsuccessful, ultrasound for femoral placement to insure success
- Landmarks with palpation with ultrasound preprocedure and/or during procedure
- Puncture with 2D US and transducing
- Radial initial palpation the US if difficult. more likely to use US in Femoral but depends on size of patient and difficulty
- Pencil Doppler
- palpation first, if unsucessful, puncture assisted with 2D ultrasound
- it depends of wich artery i intend to canulate. eg: US EVERY FEMORAL ARTERY
- pulse, then US if weak

Question 17

"How often do you use Doppler Ultrasound (acoustic signal) to assist arterial line placement?"

Most of the time	104	10.81%
Never	323	33.58%
Occasionally	**535**	**55.61%**
Total	**962**	

<u>Question 18 (branching Q17 - answer "Most of the time")</u>

"You use Doppler (acoustic signal) "Most of the time" for arterial cannulation in children because (multiple answers possible):

It is superior to other techniques to detect anatomical variations	36	21.56%
Teaching interest	11	6.59%
The learning curve is faster than with other techniques	4	2.40%
I have a higher success rate to cannulate the artery than with other techniques	**64**	**38.32%**
I need less time to cannulate the artery than with other techniques	41	24.55%
Other (please specify)	11	6.59%
Total	**167**	

Other options: free comments to answer "Other"

- Misread previous question I don't use Doppler to help with cannulation
- reduces failure rate
- enhancing familiarity with Doppler technique for straightforward cannulation hones skills/ 3d awareness with Doppler for when a tricky case comes along. However: use routinely for femoral, by palpation without USS more often for radial
- I use ultrasound much more frequently in younger children than in adolescents, whose arteries are easier to palpate
- i dont use it
- Fewer punctures
- Don't use
- I do not use doppler, I use ultrasound
- I do not use doppler
- what is easily available in my institution

Question 19 (branching Q17 - answer "Never")

"You "Never" use Doppler (acoustic signal) for arterial cannulation in children because (multiple answers possible):

I do not have the appropriate experience / training	85	23.94%
I do not have access to Doppler in our department	55	15.49%
In my clinical practice Doppler for arterial line placement does not offers any advantages over other techniques	**171**	**48.17%**
Other (please specify)	44	12.39%
Total	**355**	

Other options: free comments to answer "Other"

- less sensitive then ultrasound guided puncture
- I have never found it useful. If the artery is difficult to cannualte using palpation, USS in my experience is of little benefit
- 2D US used
- use 2 D ultrasound without doppler
- Just use ultrasound, not doppler
- Ultrasound available
- I've never really heard of that before
- I consider 2d ultrasound guidance to be a superior method
- better to use real time visual U/S
- I use real-time 2D US if palpation is difficult
- I use 2D U/S instead
- I prefer other techniques.
- I use 2D US gives me better information
- I haven't need to use it
- 2D live US superior
- We use 2 d ultrasound. Seeing is better than hearing
- Prefer 2d
- if US I prefer 2D
- Use sonosite ultrasound when necessary, not just acoustic
- I prefer ultrasound

- I use 2D real time ultrasound which is more reliable
- prefer ultrasound
- If cannula toon not use than USN
- I prefer 2D ultrasound
- I use real time 2D Ultrasound
- if I have difficulty, I switch to visual ultrasound
- 2 D real time Ultrasound is far superior
- I use regular US
- i ask for assistance from cardiac anesthesia if I am unsuccessful. they do not use ultrasound either
- I would use ultrasound over Doppler to visualize
- Use 2D echo
- I use the sonosite instead.
- We have 2D (Sonosite) machines available.
- Someone usually gets the line before the Doppler is brought in
- i prefer an ultrasound if i need help placing the line
- Pencil Doppler is better in my hands
- Don't need it
- I use visual ultrasound every time
- i find direct ultrasound visualization to be more successful
- I would ask for cut down
- 2D echo
- I always used 2d real US
- Use Ultrasound
- Our doppler equipment is outdated, and I have an ultrasound to use instead

Question 20 (branching Q17 - answer "Occasionally")

"You "Occasionally" use Doppler (acoustic signal) for arterial cannulation in children because (multiple answers possible):

I use it as a rescue technique in case of failure with other techniques	**345**	**41.22%**

I use it when I don't palpate the pulse or recognize landmarks	301	35-96%
It decreases the number of subsequent attempts of cannulation	87	10.39%
I use it as a teaching tool to locate the artery	75	8.96%
Other (please specifiy)	29	3.46%
Total	**837**	

Other options: free comments to answer “Other”

- I use it in femoral not in radial arteries
- Just learning techn
- i always use ultrasound and woull add doppler only if unsure of anatomy (unusual)
- to confirm target vessel is an artery
- I ticked the box in error thinking you meant US
- depends on where i cannulate, eg do not use it for radial artery
- I use it for femoral lines
- for femoral
- femoral artery
- US is preferred but if we need two ultrasounds and only have one, we will employ doppler
- all the above
- We use 2D ultrasound. Doppler signal is used when flow is reduced, dubious due to previous attempts or anatomical issues that make venous and arterial structures look similar on 2D views
- I use it for femoral art lines.
- not always easily available
- if 2 D ultrasound machine is not available
- If ultrasound not available
- equipment not as readily available as 2D US
- femoral arterial femoral art
- I use it when 2D ultrasound machine is not available (usually being used by a different provider)
- Rarely on the femoral or axillary sites if pulse is difficult to palpate. Prefer to palpate.
- don't use routinely for radial but do use for femoral
- use when 2d is unavailable

- Also as a teaching tool
- I plan on using it more in the future, but am still getting comfortable with this technique; hate to admit it, but when pressed for time, I just use my "tried and true" technique of not using u/s!
- I use it to cannulate femoral artery
- I allow 2 trials before using it
- 3rd preferred technique since it gives me the fewest cues about depth
- Always with femoral and when having difficulty with other sites.
- To gain experience with ultrasound

Question 21

"How often do you use 2D (2 Dimensions) Ultrasound to assist arterial line placement?"

Most of the time	226	24.09%
Never	157	16.74%
Occasionally	**555**	**59.17%**
Total	**938**	

Question 22 (branching Q21 - answer "Most of the time")

"You use Doppler (acoustic signal) "Most of the time" for arterial cannulation in children because (multiple answers possible):

It is superior to other techniques to detect anatomical variations	134	22.60%
Teaching interest	65	10-96%
The learning curve is faster than with other techniques	23	3.88%
I have a higher success rate to cannulate the artery than with other techniques	**171**	**28.84%**
I need less time to cannulate the artery than with other techniques	131	22.09%
I use it to measure the diameter of the artery to choose which catheter size to insert	51	8.60%
Other (please specify)	18	3.04%
Total	**593**	

Other options: free comments to answer "Other"

- increases success rate especially with neonates
- reduces failure rate
- safety
- Use 2D US for femoral always, sometimes for radial. Can't seem to back track- so realise don't use Doppler USS- so please can you ammend to no for previous question!
- Why do it blind? The Pedi CV kids need frequent cannulation over the years. Every site saved is a site gained for the next time around
- Fewer Punctures
- I confurm the presence of the vessel in case there is no pulse (as some kids with congenital heart defects have vascular abnormalities). Often I intentionally chose to cannulate radial artery higher in the forearm (where it's deep and cannot be palpated anymore) as the vessel is bigger there & radial A-line lasts longer & tends to give more reliable reading after bypass when distal arteries can be in vasospasm.
- availablility
- Often asked to place a line after others have failed. Helpful to determine if there is adequate flow proximal to a hematoma
- visualization aids in locating the vessel
- only if not easy by palpation
- Significantly less incidence of arteriospasm. Most neonates can be cannulated (wrist artery) in <1 min by experienced practitioners in our institution when using US
- I use it to evaluate size of ulnar vs. radial artery to choose which artery to canulate
- Helpful for determining which artery is largest: R, L, radial, ulnar
- All of the above
- Vascular access using ultrasound is the most important innovation since we starting using propofol and LMAs.
- readily available

Question 23 (branching Q20 - answer "Never")

"You "Never" use Doppler (acoustic signal) for arterial cannulation in children because (multiple answers possible):

I do not have the appropriate experience / training	56	35.44%
I do not have access to 2D Ultrasound in our department	32	20.25%
In my clinical practice 2D Ultrasound for arterial line placement does not offers any advantages over other techniques	**59**	**37.34%**
Other (please specify)	11	6.96%
Total	**158**	

Other options: free comments to answer "Other"

- 2d USS available but not suitable probe
- Why on earth would I want to? With 2D US guided puncture arterial cannulation has become a 1st pass 100% success procedure.
- I haven't need it
- Equipment size inappropriate
- just never have done it
- not very successful in my hands and very ime consuming with surgeon breathing down my neck
- Someone usually gets the job done before we need ultrasound
- I use it all of the time
- I haven't had the need for it

Question 24 (branching Q20 - answer "Occasionally")

"You "Occasionally" use Doppler (acoustic signal) for arterial cannulation in children because (multiple answers possible):

I use it as a rescue technique in case of failure with other techniques	**402**	**39.88%**
I use it when I don't palpate the pulse or recognize landmarks	346	34.33%
It decreases the number of subsequent attempts of cannulation	136	13.49%
I use it as a teaching tool to locate the artery	103	10.22%
Other (please specifiy)	21	2.08%
Total	**1008**	

Other options: free comments to answer "Other"

- For femoral artery
- use primarily for femoral arterial line
- Since the advent of US this is becoming more popular and perhaps easier and quicker In the future the 50Hz probe currently being developed will be a life changer
- I use it for femoral lines
- I use it for femoral placement
- femoral artery
- We do not have easy access to our pediatric appropriate us, we have to get it from The Peds surgeon and there is no hockey stick probe

- for femoral
- for femoral cannulation
- In association with doppler
- smaller child more likely to use from outset
- trainees start with it
- I use on very small infants
- depends on the size of the patient
- use for femorals but not routinely for radials
- would use it more often, but accurate stable placement of probe is difficult in infants/neonates. I rarely need it for older children.
- I allow 2 trials before using it or if with resident, most of the time
- Always for femoral and when peripheral site puncture is unsuccessful by palpation
- To gain experience with US

Question 25

"In the past two years, did you experience complications related to arterial line cannulation from the time of its placement to its removal?"

Yes	146	16.01%
No	**766**	**83.99%**
I prefer not to answer	0	0.00%
Total	**912**	

Question 26

"What type of complications related to arterial line cannulation did you experience (multiple answers possible)?

Hematoma	88	32.59%
Localised infection	6	2.22%
Nerve injury	0	0.00%
Permanent occlusion (severe ischemic damage)	10	3.70%
Temporary occlusion (blanching)	**113**	**41.85%**
Thrombosis / Embolism	33	12.22%
None	2	0.74%
Other (please specify)	18	6.67%
Total	**270**	

Other options: free comments to answer “Other”

- In a very sick hypotensive baby, sometimes the pulsatile vessel is the VEIN
- Not severe ischaemia damage but more than just blanching and longer lasting.
- hub detatched from catheter. patient had to go for IR-guided extraction
- a. Transient Hand ischemia (> 1day) b) In the ICU, post op day 6, During decannulation of a radial art catheter , removal of sutures, the catheter was inadvertently cut and retained within the vessel, that required a cut down for removal of catheter.
- decreased distal perfusion - femoral with leg ischemia
- Disconnection at the hub during case under the drapes
- with femoral arterial line placement in infants if hematoma develops secondary to multiple punctures
- Bloodstream infection
- the cannula separated from the hub and required return to the OR for cutdown
- very poor signal per operatively
- Line related sepsis (eg blood culture +ve)
- inadvertent intraarterial medication administration without sequelae
- Temporary occlusion
- Blood stream infection possibly related to cannula
- minor perfusion issues requring line to be removed. In our service we have had a major vascular injury from a femoral line
- Clotted off, or dislodged ---I.e., stopped working.

Question 27

“What would you usually do in case of blanching of the extremity just after an uneventful cannulation? (multiple answers possible) »

Administer a bolus of heparin (please specify the amount of units under "other")	31	1.88%
Administer a small dose of lidocaine to resolve the most likely vasospasm	252	15.25%
Administer a small dose of papaverine to resolve the most likely vasospasm	93	5.63%
Increase the rate/amount of heparin in the pump	22	1.33%

Remove the cannula immediately	210	12.71%
Wait and monitor the extremity with O2 saturation (look for arterial wave and saturation)	**686**	**41.53%**
Warm the extremity	284	17.19%
Other (please specify)	74	4.48%
Total	**1652**	

1

2 Other options: free comments to answer “Other”

- warm controlateral extremity
- 75u/kg
- ultrasound
- In case of persistent blanching, remove the cannula
- Be patient
- monitor clinically, low threshold for removal
- Remove cannula when I am successful on an alternative site.
- Observe and adopt a "wait and see approach"
- Ve
- adinister a small dose of ketanserine to resolve most likely vasospasm
- Then remove cannula
- If persistent then i remove cannula Consider brachial block to provide longer relief of spasm
- hasn't happened yet
- heparain - 10units
- ask advice
- consider nitrate patch
- Give IV fluid bolus if concerned about hypovolaemia
- My patients are often heparinised for cardiac bypass
- remove if simple measures don't work
- low threshold for removing cannula
- consider 1% of systemic dose of TPA dowmn line if no improvemetn after 20 mins warming
- Administer GTN into artery

- GTN
- Watch for 20 mins
- Check for cap refill
- never had it happen
- If these salvage techniques fail and other sites available, remove cannula.
- I haven't had this complication
- 2D ultrasound to verify flow in collateral vessels. Increase maneuvers to increase blood pressure, plus use heparin flushes. On 99% of times, the vessels recovers from spasm over 30 mins
- if no amelioration with the previous: remove the cannula
- depends on the degree of blanching: blanching without injection - remove cannula, blanching post injection - wait and monitor, may inject small dose of lidocaine
- depends on severity, depends on how hard it was to get the art line, this is usually a femoral after failing to get peripherals
- never thought about it
- 1-2
- Inject small dose of magnesium
- That's normal. You're squirting saline into an artery. It displaces the blood. Of course it blanches.
- I will place symmetric NIRS probes on both extremities (compromised and intact)
- remove catheter is persists
- don't use the aline
- nitroglycerine
- Depends on how important the line is - prebypass, it stays; marginally indicated, it comes out
- nothing
- warm opposite extremity
- Add papaverine to fluid
- visual observation of extremity with low threshold for catheter removal
- heparin drip
- I would observe if there was transient blanching after heparin flush but remove the catheter if the blanching was long-lasting.
- remove cannula if no improovement with warming and low SaO2
- Actilyse ?
- Phentolamine

- warm contralateral extremity
- start a heparin drip
- monitor waveform
- remove the cannula after waiting/monitoring if no improvement.
- have not experienced this
- Remove cannula if site does not improve prior to draping.
- If does not resolve shortly, I will remove the cannula
- Depends on severity of balnching, speed of return. Off watch very carefull and wait. If ongoing concern give heparin if no contraindication, warm limb, remove cannula, call vascular surgeons if femoral
- remove the line if significant, however this is extremely rare
- Monitor the extremity
- doppler
- monitor site
- Magnesium injection
- topical nitoglycerin
- Add papaverine to aline solution, consider alternative site. Watch and reevaluate after 5-10 min
- GTN or phentolamine
- I avoid using high pressure injections for prolonged periods of time.
- 2 units in 2 mL saline
- plastics consult
- several of the above depending on clin scen: remove vs wait/warm/monitor, lido vs NTG
- I have not experienced this complication
- If no response to above remove cannula.
- Remove catheter if blanching persists
- expectant management.

Question 28

"What solution and / or concentration of heparin do you use to keep patent the arterial line (KVO) in children < 10 Kg?"

Normal saline	277	31.26%

Heparin < 1UI/ml	110	12.42%
Heparin 1 UI/ml	**366**	**41.31%**
Heparin 2 UI/ml	109	12.30%
Heparin > 2UI/ml	5	0.56%
Other (please specify)	19	2.14%
Total	**886**	

Other options: free comments to answer “Other”

- I use Normal saline in theatre as I sample POC coagulation and don't want contamination by heparin. Once on PICU I use heparin 1IU/ml
- I don't know
- NSaline in theatre, Heparin 1U/ml used on PICU
- Heparin 0.5 u/ml
- normal saline in OR, Heparin 1 UI.mL in ICU
- heparin, unsure of concentration prepared
- Heparin 1 u/ml if no issues. Will add papaverine if there is limb compromise or poor waveform
- Unknown concentration
- NS in the OR which is changed to heparin in the NICU or PICU
- Unsure
- 250 UNITS HEPARIN IN 50 MLS
- don't know
- Majority of my hospital uses Heparin 2 UI/ml, however I prefer Normal Saline.
- policy here changed-i do not know the new policy. old was 1 unit.ml
- unknown
- ?
- Not sure
- I don't know - some small amount in the flush bag

<u>Question 29</u>

“Please indicate the minimal rate of infusion to keep the arterial line patent (ml/h) in children < 10 Kg?”

0.5 ml/h	167	19.24%
1 ml/h	**404**	**46.54%**

2 ml/h	171	19.70%
> 2 ml/h	39	4.49%
Other (please specify)	87	10.02%
Total	**868**	

Other options: free comments to answer “Other”

- no one
- no infusion
- 0.5 ml/h < 5 kg, > 5 kg 3 ml/h
- pressurised bag
- Pressure bag not infusion pump
- use inttraoperatively with out pump
- arterial Flush Bag
- it is on a pressure bag so I don't know the baseline rate
- We use a pressure bag attached to a standard transducer. I don't know what rate it infuses at.
- We use pressure bags which are 3ml per hour I believe. Again adult/Peds hospital. If they come from the floor they have heparin or papaverine at 0.5-1 ml per hr
- pressure bag
- Intermittent flushing
- pressure bag not set rate by pump
- Pressure bag
- 3 ml/hr
- no rate in OR, 0.5 mL in ICU
- on pressure bag, flush as needed
- No infusion
- Pressure line, occasional flush
- Flushes only
- only pressure bag in OR, no infusion
- whatever the transducer allows through
- intraflow device
- not on a pump
- don't know

- Don't know
- no infusion
- Don't know
- usually use a pressure bag with no hourly rate
- 0
- Pressure bag
- 3 ml/hr
- Pressure bag
- Pressurized line
- na
- Not placed in pump, use a pressure bag and flush
- pressure bag
- no rate, occasional flushes
- No infusion rate since line is flushed when abg is done or if tracing looks dampen.
- 3 m/h
- Intraflow
- no infusion ran in OR, intermittent flushing. PICU has protocol but I am not sure of details
- no infusion, periodic flushing
- pressure bag
- Pressurised bag in OR, no flow. 1 ml/hr in PICU
- use pressure bag and flush
- Intraop: not on infusion but frequently flushed. Post-op: 1 mL/hr
- icu does this-or just used the pressure bag set up
- in OR normal saline in pressure bag
- pressure bag
- in the OR we don't infuse our alines
- 0.5-1 ml/h depending on the child's weight
- pressure bag
- intermittent flush

- no rate in OR
- flush as needed
- pressure tubing
- ?
- pressure transducer
- 1.2
- intraflow device
- no infusion
- kept on a pressure bag with the heparin soulutin, not hooked to a pump
- Don't know
- via a transducer and I'm unaware of the rate
- Occasional flush, no infusion
- none used during surgery
- don'r run an infusion, but have the heparinized solution in the pressure bag
- no infusion intra-operatively
- not sure
- I don't know
- do not run anything that's for NICU babies only
- Not sure
- do not know
- pressure line
- No set infusion rate. Attached to pressure bag.
- don't usually place it on a pump
- none
- no infusion
- runs on a pressure bag
- unsure
- 1.2 cc/h
- don't know - use a pressure bag just above systolic pressure
- None

9.4.3. Question 30

“Thank you for taking part to this survey. Do you have any comments/suggestions regarding it? »

6779473	very interesting survey. Please let me know about result!Thank you!
9020830	0.9% Saline is not Normal Only put arterial lines in resuscitation of kids and usually the older child not usually under 1s
9026002	I wanted to go back and change an answer but the tool wouldn't let me I don't use Doppler because I haven't been trained in the use of that equipment and Im not sure we have access to the equipment anyway
9026171	Only problems with regular distal ischaemia are with brachial lines! My colleagues are relaxed with this route but I only VERY rarely use this route & ask nurses to watch the hand very carefully. One major problem with ischaemia with femoral art line in 30 yrs - ischaemia and lower leg amputation in 10 year old. Reason for this occurring in larger child was never clear. 20 g leadercath had been used and inserter said it went in easily.
9029021	Site of arterial line placement is contingent on the surgery being performed. For example, although I've never had a major perfusion problem with femoral artery placement in a neonate, I am aware it is possible to have serious complications with this site and I only use it when the line is essential (e.g. in bypass surgery). I will also use right axillary artery (never brachial) if there is difficulty with right radial cannulation in coarctation repair.
9033370	questions regarding ultrasound refer to my practice in femoral art lines. For radial lines I use cannula over needle with no wire and no ultrasound. Not able to explain this during survey.
9034351	I work in a district general hospital. Most of my paediatric lists are day cases.
9036407	Difficult as on an elective basis do not do major paeds but always potential for art line to be needed for emergency trauma etc so still need to be aware of the techniques
9037700	No, thank you
9039368	I have taken part in several surveys by the Association. It would be great to know the results. Often we are asked to participate however the results are not sent to us, and if it is published or made public, I would like to known where and when the results are published.
9047952	Not really! I have been in pediatric anesthesia for a long time and seen

	technology come and go but I really think ultrasound is making a huge impact on clinical practice. My fear though is for those who are trained on ultrasound and then move to places where no ultrasound is available!!
9048987	No facility for returning to previous question, so several missed by attempting to go backward
9050333	'How many attempts at one site before changing your plan' also should be part of the survey, as it may be important to call for help early if one is in trouble.
9090026	Back button for when hit the wrong answer
9090174	its structure does not allow accurate answers in some sections. e.g. type of cannula used does not include avoiding cannula with a port
9161594	There may be differences in use of ultrasound and seldinger/ catheter size& type that is related to where art line placed- that was a bit tricky to indicate on the questionnaire, so may be that info is within text. Great topic to look at !
9363505	I find the cold light source particularly useful in premature infants
10559918	It's too long and complex. I almost stopped halfway.....
10587650	more specific material for kids
10590376	We don't do any major paeds surgery or routine surgery on infants so arterial lines only used in emergencies / sick children for ITU transfers.
11745063	too long
11745116	curious if most use the transfixtion technique (through and through with backing out) and whether it is associated with more hematoma
11745156	Experience does not guarantee that expertise in a technical procedure will be attained. There are many competent operators, but it important to differentiate between competent, proficient, or expert for performing this procedure. The patient case-mix is important, cardiac vs. non-cardiac is relevant to this survey, especially when limb choice for arterial cannulation is limited by anatomical or hardware issues. Limb positioning and ensuring optimal ergonomics is essential for success, this should have been questioned. Also, sterility is relevant - how many anesthesiologists wear gloves for arterial cannulation, considering many of us rely on palpation.
11745545	If I am unsuccessful with an initial landmark radial artery puncture, I will use an U/S machine and puncture the radial artery more proximally

11746041	Most of my younger partners utilize ultrasound earlier in the process. Some are not very good at palpation techniques but excellent at 'seeing' on u/s what can't be palpated.
11746664	Question 14 is faulty. I attempted to rank the items and it automatically ranked it in order of 1-5.
11748422	Proof read it before sending it out. Multiple spelling errors. Does not reflect well on you or SPA.
11749627	I quickly move to 2d u/s if I have difficulty I use 2d in real time out of plane. Would be interested to see how people use the ultrasound with more detailed questions.
11752260	The approach at our institution is staff specific. I am both most conservative by insisting on full sterile preparation and technology drive by almost routinely using 2D-ultrasound and wire assisted placement.
11754000	I prefer 2D ultrasound
11764677	The question regarding what to do when one has an unsuccessful w/ aline placement is unclear. I typically just move up the radial artery and try again on the same extremity (not an option). I would then try the other radial artery but only switching to contralateral side is an option which does not specify site of next aline attempt. Not a well worded question in my opinion. Great study otherwise.
11773985	Someone should have edited this survery for proper English--quite a few errors exist.
11800999	Excellent survey
11807817	I will be very interested in the results since in my practice I actually place very few A-lines and it will be nice to learn what others do on a more regular basis. Thanks
11819609	find pediatric arterial line placement can be very challenging
11823783	I haven been using radial artery cannulation for mor than 20 years and its a safe technique. I published a small article: Cateterismo de la arteria radial. Revista Cubana Cirugía 1988; 27(5):28 31. I hope you enjoy reading it.
11878162	No, very good. would love to hear the results ASAP
11945374	could not drag responses for question 14
11953979	Utilize a 'baby wire' for most infant arterial lines
11992636	question 14 seemed confusing/not clear

12003761	You might ask about institutional policies about how long lines can be left in.
12145709	Need more options for use of doppler. Generally I RARELY use doppler, so 'Never' is not totally accurate, but it is very infrequent.
12150959	I think you will get a wide range of answers, esp old vs younger. I seldom use a wire but my expert cardiac people use wires a lot.
12656202	The heparin infusion is prepared by the pharmacy, I am not sure about the concentration.
12883024	good survey
14489316	Please spell check - multiple spelling errors throughout survey
14493727	With ultrasound, there is no need for blind procedures, there are less complications, and better success. Just like CVL placement, arterial ultrasound should become standard of care in children.
14496526	why the survey???
14505973	KEEP IN MIND I AM RETIRED FROM PEDIATRIC ANESTHESIA FOR 8 YEARS AND NEW TECHNIQUES HAVE BEEN ADDED (ULTRASOUND ATC)
14689561	To enhance placement of an arterial line we should look at all the different techniques and design a kit to assist with this procedure. A 24g venous catheter with non safety features that would accommodate a 0.18 mm wire that could allow for the placement of a 22g catheter would be great. Our hospital does not purchase the non safety features venous cannula. Any suggestions regarding this issue would be greatly appreciated.
14736800	It would be easier if every question had the same format.
14744227	As mentioned, I specifically use #22 Angiocath for my a-line access, occasionally #24 Angiocath - they are far superior to the safety iv catheters.
14745117	Great questions! Always good to make us think about what we do.
14748116	Can you distribute the survey results to the participants. Thanks
14764502	error on ultrasound doppler answer> could not go back
14773462	use ultrasound more and more , you only had the choice of never, always, occasionally, I answered occasionally but it is rather about 50 % of the time
16219426	I don't do any extremely high acuity infants. We don't do cardiac, and we don't do transplants. So, arterial line use in our pediatric patients is rare. Usually it's in the context of craniotomies or other oncological surgeries.

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9.5. Comparison between Gauge and French Scales

Gauge Size	External Diameter (mm)		French Size	External Diameter (mm)
29	0.33		1	0.33
27	0.406			
24	0.559			
			2	0.67
22	0.711			
20	0.902			
			3	1
18	1.27		4	1.35
16	1.651			
14	2.108		6	2
(Tableau tiré de SAI Infusion Technologies (www.sai-infusion.com)				

9.6. Arterial catheters sizing related to weight and site of cannulation

Examples of current recommendations from: Textbook of Pediatric Emergency Procedures, 2nd edition, King C. Lippincott. 2008						
Arterial Sites	< 10 Kg		10-40 Kg		> 40 Kg	
	Gauge	French	Gauge	French	Gauge	French
Radial, Tibialis posterior, Dorsalis pedis ou Brachial	24 ou 22	3.0 – 4.0	22		22 ou 20	
Femoral ou Axillar	20 ou 18		18 ou 16	4.0 – 5.0	18, 16 ou 14	5.0 – 6.0

Recent textbook's table showing too large catheters for femoral or axillar sites in babies less then 10 Kg.

10. POSSIBLE EXTENSION OF THIS WORK TO THE SWISS PEDIATRIC ANESTHESIA SOCIETY (SPAS)

In Switzerland, there are five university centres doing tertiary paediatric anaesthesia, for a broad spectrum of highly specialized surgeries, like cardiac congenital surgeries, complex paediatric thoracic surgeries or neonatal surgical emergencies (necrotizing enterocolitis, diaphragmatic hernia, etc.). All five centres possess NICU and PICU facilities dealing with unstable patients.
Consequently, invasive hemodynamic monitoring and arterial lines in children or neonates are a daily part of their activity.

Very probably, the diversity and heterogeneity of practices will reflect over centres with different influences.

It could be interesting to reshape another questionnaire, designed for the SPAS, taking in account the errors of the previous survey (less questions, tracking cookies for targeted reminders, all questions compulsory to answer in order to finish the survey, etc.), mainly aiming at questioning:

- Sterility and standardization of procedures
- Sites of arterial access with regards to procedures and specialities (cardiac vs. non-cardiac)
- Implementation of ultrasound for arterial access (and vascular access in general)
- Teaching of ultrasound-guided procedures
- Type of devices used and rate of complications

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11. SUMMARY FOR ARTERIAL CANNULATION TECHNIQUES AND DEVICES ACCORDING TO AGE AND SITE OF INSERTION (non cardiac surgeries)

Technique of insertion	- Threading over a wire - Direct or posterior wall puncture	- Threading over a wire - Direct or posterior wall puncture	- Threading over a wire - Direct or posterior wall puncture	- Threading over a wire - Direct or posterior wall puncture	- Threading over a wire - Direct or posterior wall puncture
Technique of location	- Landmarks for umbilical - Ultrasound - Transillumination - Doppler	- Landmarks - Ultrasound - Doppler	- Landmarks - Ultrasound - Doppler	- Landmarks - Ultrasound - Doppler	- Landmarks - Ultrasound - Doppler
Cannula size	- 24 G - 2,5 Fr	- 24 G - 22 G - 3 Fr - Depending on RAID[1]	- 22 G - 3 Fr	- 22 G - 20 G - 3 Fr - 4 Fr	- 20 G - 4 Fr
Alternative site of insertion	- Radial - Femoral - Tibial - Brachial	- Ulnar - Femoral - Tibialis - Brachial - Axillary - Pedialis	- Ulnar - Femoral - Tibialis - Brachial - Axillary - Pedialis	- Ulnar - Femoral - Tibialis - Brachial - Axillary - Pedialis	- Ulnar - Femoral - Tibialis - Brachial - Axillary - Pedialis
Primary site of insertion	Umbilical	Radial	Radial	Radial	Radial
Age	**Premies**	**0-6 months**	**6-12 months**	**1-10 years**	**> 10 years**

1. RAID = Radial Artery Internal Diameter (as assessed by ultrasound prior to cannulation: Varga EQ et al., 2013)

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12. PROPOSAL FOR AN ALGORITHM OF CANNULATION

In conclusion if this work, a proposal of an algorithm for arterial cannulation in children, has been based on the data gathered throughout the E-survey and the reviewed literature.

As a preliminary statement to this chapter I have to make it clear that this algorithm is based on a personal work, shared with my colleagues of Montreal, however can not be translated "as it is" to other hospital department without prior consultation taking in account local policies and individuals. This algorithm could be a base for future discussion and possible validation studies.

The decision to insert an arterial catheter is a multifactorial process, based on a balance between benefits (close hemodynamic monitoring, frequent blood samples drawing) and risks (hematoma, trauma to adjacent anatomical structures, ischemic damages). It will never be overstated that the final decision is left to the clinician in charge of the patient, supported "in fine" by his/her experience, technical skills, practices and habits of neighbour department (PICU) whatever the algorithm shows. Hence, in this chapter we will not develop on the medical indication to arterial cannulation but how to deal with different techniques, sites if insertion and alternatives.

Firstly, I would like to make a difference between the use of arterial catheters during cardiac and non-cardiac surgeries, as those patients' challenges and population differ between congenital heart diseases (CHD) and other medical conditions. Mostly because such patients are "frequent flyers" to heavy surgeries that need close hemodynamic monitoring and multiple puncture attempts increase the risk of complications related to arterial cannulation. Moreover, the blood pressure physiology will be disturbed in CHD patients as the may live under cardiac assistance, either mimicking blood pressure oscillations (Ventricular Assist Devices - VAD) or not (continuous flow like Extracorporeal Corporeal Membrane Oxygenation). The unique pathophysiology generated by the cardiopulmonary bypass (CPB) circuit, in particular the rush of inflammation's mediators may lead to post-CPB vasoplegia or vasoconstriction, thus rendering the choice of cannulation even more complex. For example, post-CPB, the radial site is more prone to arterial wave artefacts (damping due to vasoconstriction) and the femoral site is less prone to constriction (Chauhan S 2000; Cho HJ 2017). On the other side, cannulating the root of a limb, as the femoral site, expose to more debilitating consequence in case of permanent ischemia and subsequent amputation.

Secondly, I will exclude arterial cannulation outside the perioperative settings, in particular at PICU or NICU. Even if, definitively, there are similarities (indications and techniques), the management of vascular catheters for a prolonged time probably differs than the limited perioperative period. Moreover, the questionnaire didn't target that population of clinicians.

Finally, I will also exclude the catheterization laboratory, because the questionnaire wasn't designed to assess that speciality and they use specific devices with sheath's diameter much bigger than conventional arterial catheters. Of note, there is a growing body of literature on the "cath lab" and anaesthesiologists should stay tuned with developments in that field, in particular regarding the management of acute (traumatic) or delayed (ischemic) complications (Kayassi A et al., 2014). Of note, an interesting table summarizing predictors of radial artery spasm during transradial catheterization access (Table A - Predictors of Radial Artery Spasm - reprinted from Tuncez A et al., 2013).

Reference	Independent Predictors of RAS	OR (95% CI)
Ruiz-Salmeron et al. (2005)[22]	radial artery anomaly more than 3 catheters used painful cannulation post-vasodilatation radial artery diameter phentolamine instead of verapamil	5.1 (2.2-11.4) 3.0 (1.9-4.7) 2.6 (1.4-4.9) 0.98 (0.98-0.99) 1.8 (1.1-2.9)
Deftereos et al. (2010)[24]	FMD lower than 2.95%	3.97 (1.70-9.29)
Jia et al. (2010)[20]	small radial artery diameter diabetes mellitus female sex unsuccessful first attempt of cannulation	4.02 (1.26-12.19) 2.14 (1.57-7.45) 1.74 (1.14-3.84) 1.46 (1.21-2.59)
Rathore et al. (2010)[18]	female sex age diabetes mellitus	2.01 (1.31-3.09) 0.96 (0.95-0.98) 1.84 (1.22-2.76)
RAS = radial artery spasm; FMD = flow mediated dilatation; OR = odds radio; CI = confidence interval.		

The radial artery represents the first choice of cannulation in every category of patients. It is a reliable site for hemodynamic measurements or blood sampling, easily accessible to any kind of puncture technique (landmarks, ultrasound or other visualization techniques), close to surface and with an easy maintenance. Ultrasound guidance has shown superiority over landmarks in adult and children (Cochrane review 2016; Shiloh AL et al., 2011; Gao YB et al., 2015; Schwemmer U et al., 2006; Hanse MA et al., 2014). Pre-procedural test of ulno-palmar arch patency has been voluntarily let aside as, up to now, we do not have a reliable, reproducible test, with clear cut-off. And will stay so for a long time. Indeed, the probability of a permanent ischemic event is rare (<1%), it would hence take several thousands of patients to compare different techniques of ulno-palmar evaluation and detect a significant difference. Probably the improvement of recent vascular imaging technologies, like NIRVIS® for Near Infrared Vascular Imaging System (Cuper NJ et al., 2012) or NIRS® for Near Infrared Spectroscopy may help to evaluate arterial flow in a dynamic way. The idea is not only to see the arterial flow but also to determine if the residual blood supply is enough to perfuse the cells downstream from an arterial cannula.

It seems however a safe practice to evaluate the internal diameter of the vessel (RAID - Radial Artery Internal Diameter - Varga EQS et al., 2013) in order to tailor the size of cannula to insert. The ratio between the internal diameter (ID) of the artery and the outer diameter (OD) of the cannula shouldn't be smaller than 3. In other words, the amount of lumen occupied by the catheter shouldn't exceed 1/3d of the RAID. For example, a catheter of 3Fr (1mm) could fit inside a 3mm vessel or a 26G (0,45mm OD) venous cannula could be inserted inside an 1,35mm ID artery, that is consistent with an infant or neonate's radial artery (Varga SEQ et al., 2013).

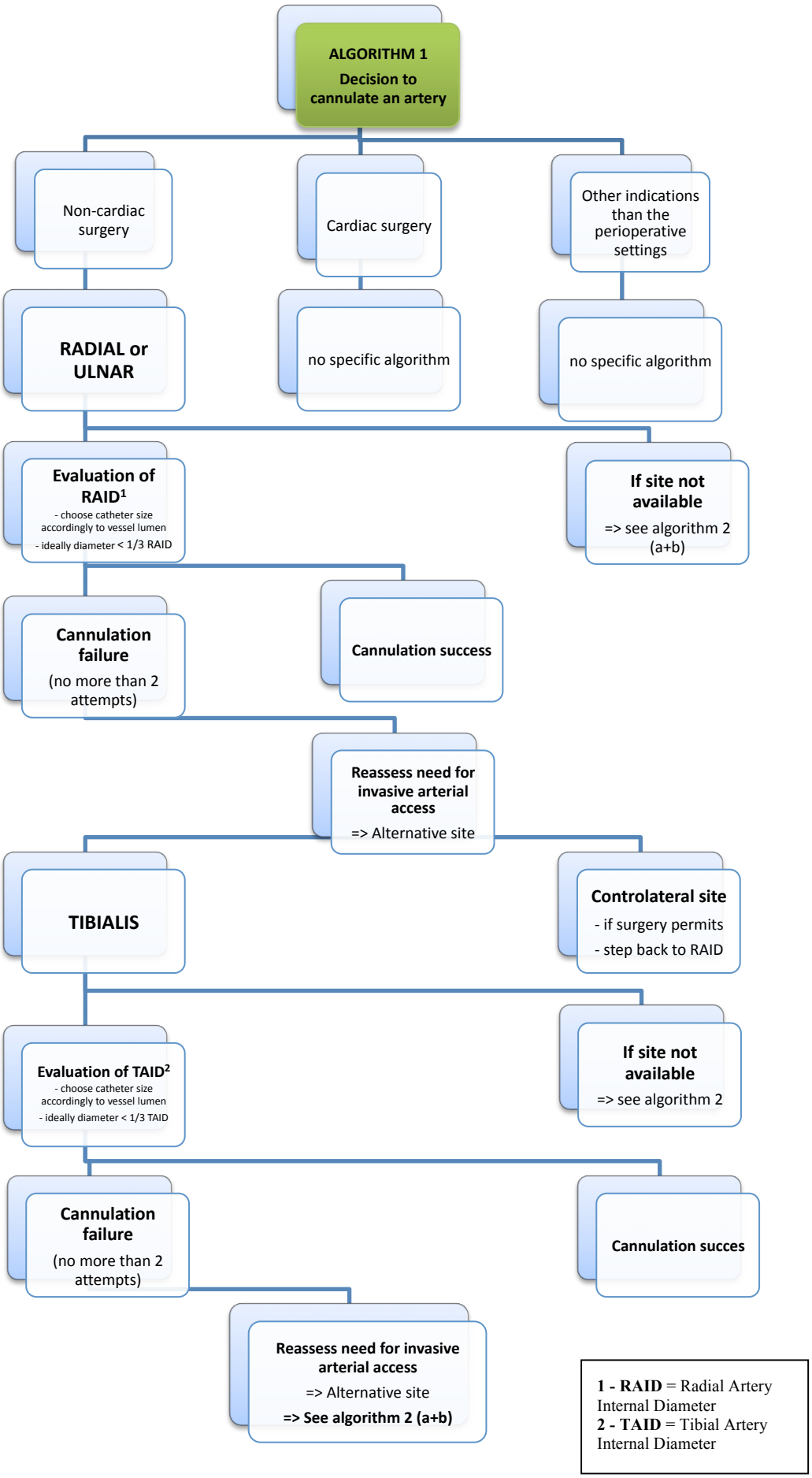
The ulnar artery should be considered also a first choice, as it is anatomically as big, sometimes bigger, than the radial. However, one should pay attention to the relatively massive and very close to artery ulnar nerve. Plus practitioners should be aware that this artery can be quite mobile under the skin, thus rendering the punction more technical. Taking in account those considerations, an ulnar artery catheter is as easy to fix and to maintain than a radial one (Karacalar S et al., 2007).

Regarding alternatives sites in case of puncture failure, if the surgery permits it, practitioners should try on the controlateral limb. Of note, it is not safe to puncture on the same limb, same level. For example, one should never puncture the ulnar artery on the same limb after a radial attempt, as this may highly promote ischemic events.
When the controlateral site has been depleted, the next step seems to go for the tibialis posterior artery (TPA). Indeed, this site has recently attracted attention under the light of the study of Kim EH (Kim EH et al., 2017), who has shown that the ID of that artery is as large as the radial site and bigger than the Dorsalis pedis artery (DPA). Moreover, the first pass cannulation success was similar between the radial and the posterior tibial arteries, higher than the one for the dorsal artery of the foot. The cannulation of the posterior tibial artery is a well-known site in the NICU settings, but less used perioperatively by anaesthesiologists. One of its advantages is a collateral circulation, similar to the ulno-palmar arch in the hand, called the plantar arch, which runs between the DPA and the TPA (Tutar O et al., 2016). Thus, TPA's site deserves more studies and seems promising.

A chapter much more open to debate is represented by the next step in the algorithm, when radial or ulnar sites, then PTA sites have been depleted and when the practitioner is pushed to puncture upstream of a previous cannulation attempt. In all likelihood, it seems safer to choose a site with anatomical collaterals, like the femoral or axillar sites. Brachial site have been described as a safe cannulation site, but only by one team (Schindler E et al., 2005) who is very experienced with that procedure.

In the end, I have excluded umbilical site that is irrelevant for the perioperative setting. I have done the same for other "exotic" site like the temporal artery, which is anecdotically described as a safe alternative (Escriba F et al., ESPA 2015 abstract) but is known since long ago as a dangerous site with potential devastating air embolism due to its very close vicinity to the cerebral circulation (Prian GW et al., 1979).

The following algorithms explore the decision tree once the decision is taken to cannulate an artery (Algorithm 1), followed by 2 branching algorithms, in case alternative sites are needed, on the upper limbs (Algorithm 2-a) or the lower limbs (Algorithm 2-b).


ALGORITHM 1
Decision to cannulate an artery
Non-cardiac surgery
Cardiac surgery
Other indications than the perioperative settings
RADIAL or ULNAR
no specific algorithm
no specific algorithm
Evaluation of RAID1
- choose catheter size accordingly to vessel lumen
- ideally diameter < 1/3 RAID
If site not available
=> see algorithm 2 (a+b)
Cannulation failure
(no more than 2 attempts)
Cannulation success
Reassess need for invasive arterial access
=> Alternative site
TIBIALIS
Controlateral site
- if surgery permits
- step back to RAID
Evaluation of TAID2
- choose catheter size accordingly to vessel lumen
- ideally diameter < 1/3 TAID
If site not available
=> see algorithm 2
Cannulation failure
(no more than 2 attempts)
Cannulation succes
Reassess need for invasive arterial access
=> Alternative site
=> See algorithm 2 (a+b)
1 - RAID = Radial Artery Internal Diameter
2 - TAID = Tibial Artery Internal Diameter

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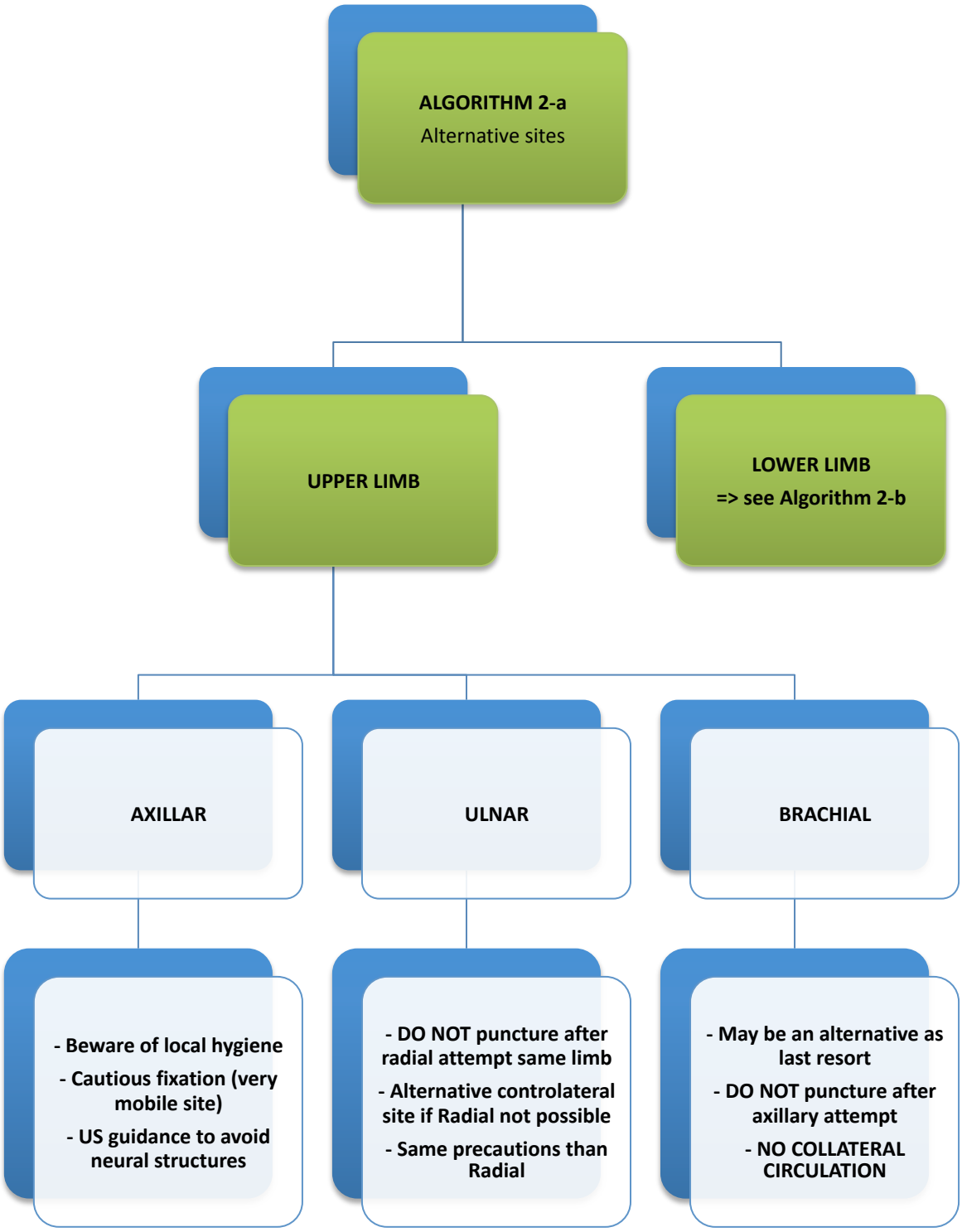
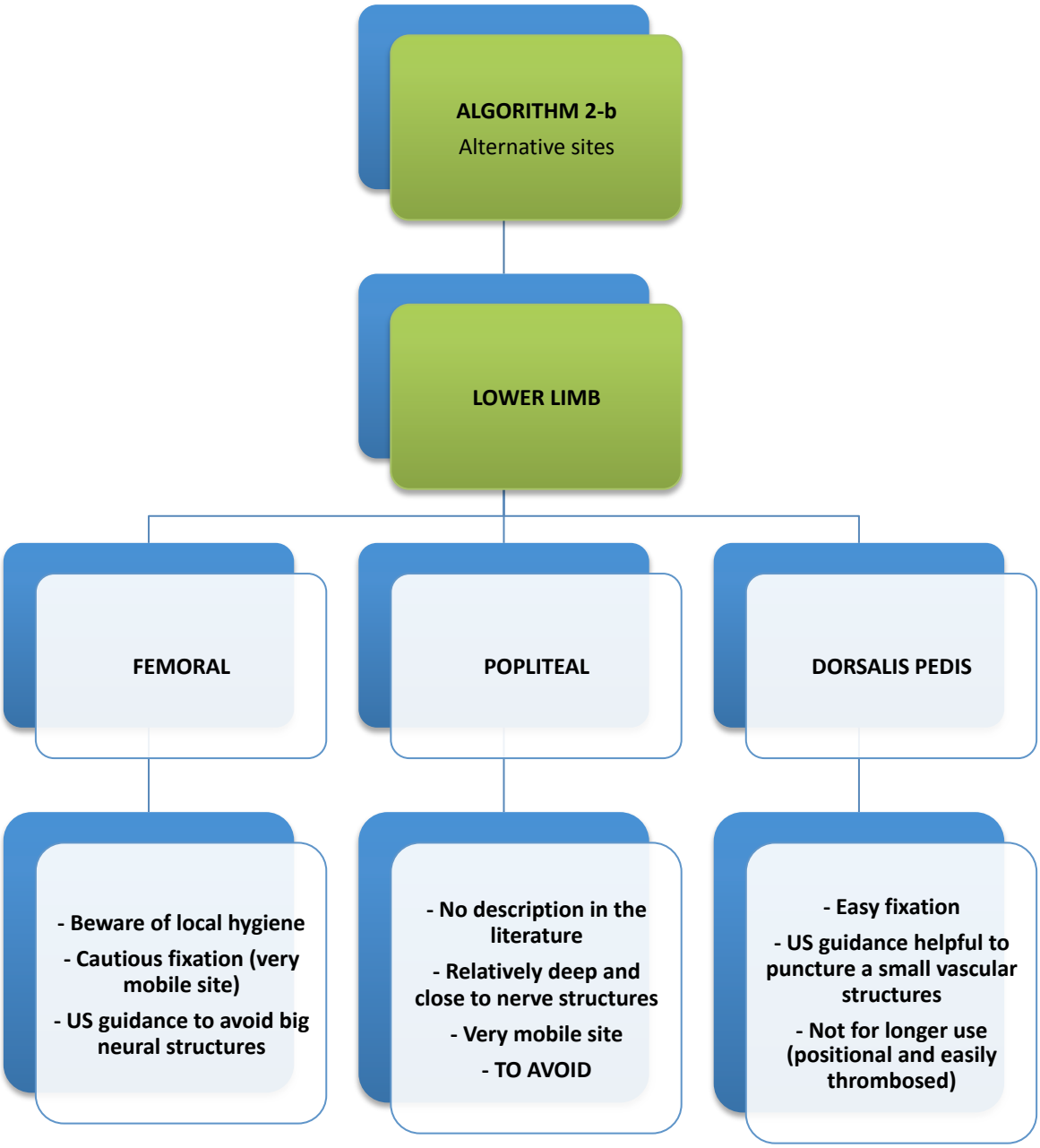


Always aim for a catheter smaller or equal to 1/3 of the internal artery diameter
Never attempt a cannulation on the same limb lower or higher than a previous attempt



1

Always aim for a catheter smaller or equal to 1/3 of the internal artery diameter
Never attempt a cannulation on the same limb lower or higher than a previous attempt

2
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4