Cardiac Intensive Care

Ultrasound-Guided Femoral Arterial Cannulation in Neonates Undergoing Cardiac Surgery or Catheterization: Comparison of 0.014-Inch Floppy Versus 0.019-Inch Straight Guidewire

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Objectives: Percutaneous femoral artery cannulation can be technically challenging in small infants.

Design: We designed a prospective randomized trial to compare the use of two different guidewires for femoral arterial cannulation in neonates undergoing cardiac surgery or catheterization.

Settings: Cardiac ICU in a university hospital.

Patients: One-hundred twenty-four children were enrolled in this prospective study, with 64 being randomized to the 0.019-inch straight guidewire group and 60 to the 0.014-inch floppy guidewire group.

Interventions: Femoral artery cannulation.

Measurements and Main Results: The study period was limited to 10 minutes at the first site of arterial puncture. The time to complete cannulation, number of successful cannulation on first attempt, number of attempts, and number of successful cannulations were compared. The number of successful cannulations and successful cannulations on first attempt were higher in 0.014-inch floppy guidewire group ($p = 0.001$; $p = 0.002$, respectively). The time to complete cannulation was significantly shorter, and the number of attempts was lower in 0.014-inch floppy guidewire group ($p = 0.001$). Among the neonates less than 2000*g*, the number of attempts and time to complete cannulation were significantly lower ($p < 0.001$), and number of successful cannulation on first attempt and number of successful cannulations were significantly higher ($p < 0.028$; $p < 0.001$, respectively) in the 0.014-inch floppy guidewire

Conclusions: Using 0.014-inch floppy guidewire for femoral arterial cannulation in particularly very small neonates provides significant improvement in first attempt success, number of successful cannulations, number of attempts, time to complete cannulation. (*Pediatr Crit Care Med* 2019; 20:608–613)

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The authors have disclosed that they do not have any potential conflicts of interest.

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DOI: 10.1097/PCC.0000000000001916

Key Words: 0.014-inch floppy guidewire; 0.019-inch straight guidewire; congenital heart disease; femoral arterial cannulation; neonates

Continuous monitoring of blood pressure is usually achieved by percutaneous catheterization of the radial artery in children. However, catheterization of the radial artery can be difficult in neonates and is not always achieved. Alternate choices include percutaneous catheterization of the femoral artery and open catheterization (cutdown) of the radial artery in neonates (1–3).

Almost all kits available for femoral arterial cannulation are not appropriate for neonates. Failure to advance the guidewire into arterial lumen of small neonates when the Seldinger technique is used can represent a major problem even after successful puncture of the artery (4, 5).

In our institution, the technique of ultrasonography guided femoral artery cannulation is well established as a routine in all neonates undergoing cardiac procedures. Before we conducted this study, femoral artery cannulation was performed with 0.014-inch floppy guidewire in some cases of difficult cannulation in our institution. These guidewires are important components of successful coronary artery interventions to access target vessels and crossing the lesions (6).

Our hypothesis is that the ultrasound-guided femoral artery cannulation using 0.014-inch floppy guidewire is superior to the femoral artery cannulation using 0.019-inch straight guidewire in neonates. We designed a prospective randomized trial to compare the use of 0.014-inch floppy guidewire versus 0.019-inch straight guidewire in neonates undergoing cardiac surgery or catheterization.

MATERIAL AND METHODS

This study was approved by Ethics Committee of Altinbas University School of Medicine. Informed consent was obtained from all individual participants included in the study.

Data were prospectively gathered from neonates with congenital heart disease undergoing cardiac surgery or catheterization in our cardiac ICU between March 2014 and July 2018. Patients were randomly assigned by using a random-numbers table to one of two groups: 1) femoral artery cannulation using ultrasonography guidance with 0.019-inch straight guidewire or 2) femoral artery cannulation using ultrasonography guidance with 0.014-inch floppy guidewire. Patients with hemodynamic stability or requiring emergency surgery were excluded.

All infants were mechanically ventilated and underwent induction of general anesthesia using fentanyl (2–3 μg/kg IV) in combination with vecuronium (0.1 mg/kg IV).

The ultrasound-guided technique was performed as follows: GE 12L-RS broadband linear array transducer (5–13 MHz) for Vivid-3 echocardiography device (GE Vingmed, Horten, Norway) was placed in a sterile sheath. After the localization of the target vessel, 22-gauge introducer needle was inserted at the edge of the transducer and directed according to the ultrasound image. A 0.019-inch 22 cm straight guidewire (Plastimed Corporation, Cedex, France) was used in 0.019-inch straight guidewire group. A cut 0.014-inch standard floppy coronary guidewire (Runthrough; Terumo Interventional Systems, Tokyo, Japan) was used in 0.014-inch floppy guidewire group (**Fig. 1**). Guidewire was shortened to 22 cm using sterile scissors in order to better manipulate during the procedure. The catheter (PTFE Seldicath 2F; Plastimed Corporation) was inserted over the wire and the guidewire removed.

All the catheters were inserted by the same-trained operator who was experienced in the insertion technique. Demographic data in inserting femoral artery cannulation by both techniques were recorded. The study was limited in a period of 10 minutes at the first site of arterial puncture and the operator was blinded to the clock. The start time was the first insertion of the introducer needle through the skin. The end time of the procedure was the first aspiration of blood through the catheter inserted in the femoral artery, if the operator was successful at the first site of catheterization. Successful arterial cannulation, the number of attempts (reinsertion following withdrawal), and successful cannulation on first attempt were recorded. If arterial cannulation failed within 10 minutes, the study was ended. At this point, the operator used the technique of his choice at the contralateral femoral artery.

Statistical analysis was performed using the SPSS Version 20.0 program (SPSS, Chicago, IL).

Previous power analysis revealed that an estimated minimal sample size of 58 patients/group was required to detect an increase in successful femoral artery cannulation on first attempt rate from 25% to 50% with a power of 0.80 and an α of 0.05. Overall success rate for femoral artery cannulation rate on first attempt was 25% in neonates at our institution. We consider an increase to 50% in successful femoral artery cannulation on first attempt to be clinically significant and important in reducing the incidence of perfusion-related complication rates due to repeated attempts. Continuous data were reported as mean ± SD and were compared between the two groups using Student *t* tests. Categorical data were reported as numbers and percentages and were compared between the two groups by Fisher exact test. *p* values of less than 0.05 were considered statistically significant. Linear correlations were analyzed using the Pearson or Spearman bivariate two-tailed method. Receiver operating characteristic (ROC) curve was used to select the optimal cut-off of the best-correlated variables to unsuccessful femoral artery cannulation.

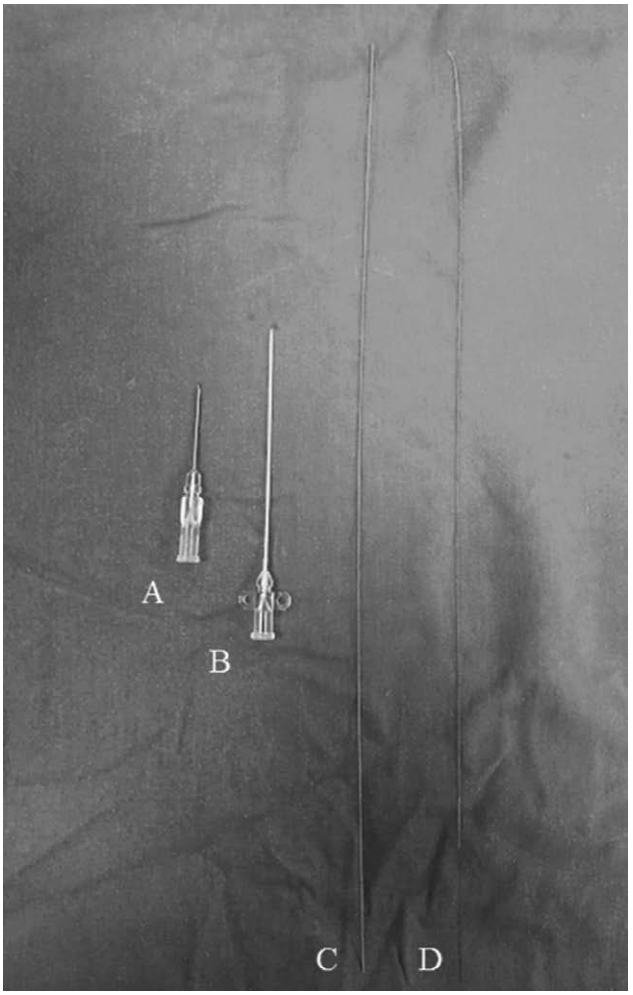

Figure 1. Seldinger equipment used in study groups for percutaneous cannula insertion: 22-gauge introducer needle (**A**); PTFE Seldicath 2F, Plastimed Corporation (Cedex, France) (**B**); 0.019-inch 22 cm straight guidewire (Plastimed Corporation) (**C**); and cut 0.014-inch standard floppy coronary guidewire (Runthrough, Terumo Interventional Systems, Tokyo, Japan) (**D**).

RESULTS

One-hundred twenty-four children were enrolled in the study, with 64 being randomized to the 0.019-inch straight guidewire group and 60 to the 0.014-inch floppy guidewire group. **Table 1** presents the demographic data and the distribution of cardiac procedures. There were no statistically significant differences in age, gender, weight, and systolic blood pressure between the two study groups.

Time to complete cannulation was shorter (549 ± 76 vs 471 ± 59 s; difference in mean, 78; 95% CI of difference, 54–102;

TABLE 1. Demographics and Results of 142 Patients Undergoing Femoral Arterial Cannulation Using Ultrasonography Guidance With 0.019-Inch Straight Guidewire and Femoral Cannulation Using Ultrasonography Guidance With 0.014-Inch Floppy Guidewire (Group 2)

Characteristics	0.019-Inch Straight Guidewire Group (*n* = 64)	0.014-Inch Floppy Guidewire Group (*n* = 60)	*p*
Age, d	9.2 (1–26)	8.3 (1–25)	0.69
Weight[a] (*g*)	2,514 (780–3,600)	2,580 (800–3,500)	0.62
Gestational age[a] (wk)	35.7 (27–42)	36.1 (27–42)	
Sex (male:female)	35/29	38/22	0.36
Systolic blood pressure during first attempt (mm Hg)	78	76	0.40
Femoral artery diameter (mm)	2.53	2.51	0.96
Cardiac procedure, *n* (%)			
Cardiac interventions	20 (53)	18 (47)	0.88
Cardiac surgery	44 (51)	42 (49)	088
Successful cannulation at first site, *n* (%)	44 (69)	56 (93)	0.001
Successful cannulation at first attempt, *n* (%)	16 (25)	32 (53)	0.002
Cross over to			
Other femoral artery	20 (31)	4 (7)	0.001
Other technique	8 (12)	0 (0)	0.014
Time of successful cannulation or failure at one site (s), *n* (%)	550 (76)	469 (59)	< 0.001
Number of attempts	3 (1–4)	1 (1–4)	< 0.001
Complication rate, *n* (%)	20 (31)	7 (12)	0.009
Blood loss (mild)	5 (8)	2 (3)	0.44
Absent pulse	15 (23)	5 (8)	0.028

Values are expressed as means with interquartile range shown in parentheses.
[a]At the time of femoral artery cannulation.

$p = 0.001$), and the number of attempts was lower (3 [1–4] vs 1 [1–4]; difference in median, 1; 95% CI of difference, 1.44–2.07; $p = 0.001$) in the 0.014-inch floppy guidewire group compared with the 0.019-inch straight guidewire group.

The number of successful cannulations on first attempt was higher in the 0.014-inch floppy guidewire group than in the 0.019-inch straight guidewire group (16/64 [25%] vs 32/60 [53%]; $p = 0.002$).

The number of patients who had successful cannulation was 31 of 53 (58%) and 40 of 53 (75%) in the 0.014-inch floppy guidewire group and the 0.019-inch straight guidewire group, respectively ($p = 0.001$).

In all the remaining cases, cannulation was performed by the same operator mostly with the assigned technique. Although arterial cannulation was eventually achieved in all patients, the operator decided on a crossover from the femoral artery cannulation technique using ultrasonography guidance with 0.014-inch floppy guidewire at the contralateral femoral artery in eight of 24 cases in 0.019-inch straight guidewire group.

Postterm gestational age, weight, and femoral artery diameter at the time of femoral artery cannulation had significant univariate correlation with unsuccessful femoral artery cannulation at the first site using ultrasonography guidance with 0.019-inch straight guidewire ($r = –0.92$, $p < 0.001$; $r = –0.89$, $p < 0.001$; $r = –0.94$, $p < 0.001$, respectively) (**Table 2**).

Patients weight less than 1,900*g* (sensitivity 82%, specificity 85%), postterm gestational age less than 32 weeks (sensitivity 85%, specificity 87%), and femoral artery diameter less than 1.9 mm (sensitivity 86%, specificity 88%) at the time of femoral artery cannulation were the best discriminant cut-offs of unsuccessful femoral artery cannulation at the first site using ultrasonography guidance with 0.019-inch straight guidewire on ROC analysis.

Data of low birth weight neonates with less than 2,000*g* of body weight in each group were reported in **Table 3**. The number of attempts and time of attempted cannulation were significantly lower in the 0.014-inch floppy guidewire subgroup compared with the 0.019-inch straight guidewire subgroup ($p < 0.001$, respectively). Number of successful cannulations

TABLE 2. Univariate Indicators of Unsuccessful Femoral Artery Cannulation on First Attempt Using Ultrasound Guidance With 0.019-Inch Straight Guidewire

Variables	*r*	*p*
Age (d)	0.08	0.59
Weight (*g*)[a]	−0.89	< 0.001
Gestational age[a] (wk)	−0.92	< 0.001
Sex (male:female)	−0.13	0.94
Systolic blood pressure during first attempt (mm Hg)	0.19	0.12
Femoral artery diameter (mm)	−0.94	< 0.01

[a]At the time of femoral artery cannulation.

on first attempt and number of patients with successful cannulation were significantly higher in the 0.019-inch straight guidewire subgroup compared with the 0.014-inch floppy guidewire subgroup ($p < 0.028$; $p < 0.001$ respectively).

Blood loss was mild in seven patients including five in the 0.019-inch straight guidewire group and two in the 0.014-inch floppy guidewire group. Patients did not require blood transfusion after procedure. Pedal pulse discrepancies by both palpation and Doppler occurred in 20 patients including 15 in the 0.019-inch straight guidewire group and five in the 0.014-inch floppy guidewire group ($p = 0.028$) (Table 1). Of these 20 patients, absent pedal pulse occurred in 13 with less than 2,000*g* of body weight including 11 in the 0.019-inch straight guidewire subgroup and two in the 0.014-inch floppy guidewire subgroup ($p = 0.005$) (Table 3).

Absent pulse occurred in twelve after unsuccessful femoral artery cannulation at the first site including ten in the 0.019-inch straight guidewire group and two in the 0.014-inch floppy guidewire group. Absent pedal pulse occurred after femoral artery cannulation in remaining eight patients including five in the 0.019-inch straight guidewire group and three in the 0.014-inch floppy guidewire group. Intensivists chose not to remove femoral artery catheters from the remaining patients with absent pulses before medication. All patients with absent pedal pulse were treated with IV pentoxifylline (5 mg/kg/hr for 6 hr). All pulse discrepancies and absent pulses recovered within 6 hours after procedure.

DISCUSSION

In our institution, the technique of ultrasound-guided femoral arterial cannulation is well established as a routine in the ICU in all pediatric patients even below 1 kg before cardiac surgery or catheter intervention. However, cannulation of the femoral artery generally presents a problem in the case of small children because catheterization may easily fail due to the small vessel diameter. The advancement of the guidewire into the femoral artery of small infants is difficult, particularly if the wire is curved or J-shaped (4, 5).

The use of the Cook Cope Nitinol Mandril guidewire Machotta et al (7) was recently in order to avoid such problems. However, Nitinol Mandril guidewire is not available in our country. Furthermore, there were no reports that demonstrated advancement of the Nitinol Mandril guidewire into the femoral artery in neonates.

Using a 0.014-inch floppy guidewire provides smooth manipulation even in tortuous, tight stenotic distal lesions in coronary interventions (6, 8, 9). Femoral arteries in neonates have similar calibration with distal coronary arteries in adults.

TABLE 3. Data of Low Birth Weight Neonates With Less Than 2,000*g* Undergoing Femoral Arterial Cannulation Using Ultrasound Guidance With 0.019-Inch Straight Guidewire and Femoral Cannulation Using Ultrasonography Guidance With 0.014-Inch Floppy Guidewire

Variables	0.019-Inch Straight Guidewire Subgroup (*n* = 18)	0.014-Inch Floppy Guidewire Subgroup (*n* = 16)	*p*
Successful cannulation at first site, *n* (%)	6 (33)	14 (87)	0.028
Successful cannulation at first attempt, *n* (%)	2 (11)	7 (43)	< 0.001
Cross over to			
Other femoral artery	12 (67)	2 (12.5)	0.002
Other technique	8 (44)	0 (0)	0.003
Time of successful cannulation or failure at one site (s), *n* (%)	570 (49)	458 (70)	< 0.001
Median number of attempts	3 (1–4)	1 (1–4)	< 0.001
Complication rate, *n* (%)	14 (77)	4 (12)	0.005
Blood loss (mild)	3 (16)	2 (12)	0.73
Absent pulse	11 (61)	2 (12)	0.005

Values are expressed as means with interquartile range shown in parentheses.

Therefore, we decided to compare the use of 0.014-inch floppy guidewire versus 0.019-inch straight guidewire in neonates in this study. The shortened guidewire was manipulated easily during the procedure. A 2F catheter could be passed over the cutted guidewire smoothly. To the best of our knowledge, no publication on the topic of pediatric arterial cannulation guided by ultrasound with 0.014-inch floppy guidewire is available.

In our study, the first attempt success was remarkably increased in the 0.014-inch floppy guidewire group as compared with the 0.019-inch straight guidewire group (53% vs 25%; $p = 0.002$). The number of patients who had successful cannulation in the first side was 31 of 53 (58%) and 40 of 53 (75%) in the 0.014-inch floppy guidewire group and the 0.019-inch straight guidewire group, respectively ($p = 0.001$).

Femoral arterial cannulation is more challenging than femoral vein cannulation in children because the femoral artery is tiny and not amenable to expansion with positioning or volume loading particularly in young infants. Although recent studies suggest that ultrasound-guided femoral arterial cannulation has high success rate in children, considerable limitation of these studies is the lack of young infants and neonates in whom success rates might be lower (10–12).

In the present study, postterm gestational age, weight, and femoral artery diameter at the time of femoral artery cannulation had significant univariate correlation with unsuccessful femoral artery cannulation at the first site using ultrasonography guidance with 0.019-inch straight guidewire. The analysis for patients less than 1,900*g* and postterm gestational age less than 32 weeks and femoral artery diameter less than 1.9 mm hints that femoral artery cannulation using ultrasonography guidance with 0.014-inch floppy guidewire might be even more useful in small neonates than femoral artery cannulation using ultrasonography guidance with 0.019-inch straight guidewire.

The subgroup analysis for neonates with less than 2,000*g* demonstrates that using ultrasonography guidance with 0.014-inch floppy guidewire might be even more useful than using ultrasonography guidance with 0.019-inch straight guidewire for femoral artery cannulation in low birth weight neonates (Table 3).

Femoral artery cannulation was successfully performed with the use of 0.014-inch floppy guidewire at the contralateral femoral artery in eight of 20 very small neonates with failed femoral artery cannulations at the first side using 0.019-inch straight guidewire. Thus, femoral arterial cannulation was eventually achieved in all patients in this study. This suggests that the use of 0.014-inch floppy guidewire is a good alternative in difficult cases after failure with the 0.019-inch straight guidewire.

Absent pulse occurred in more than half of the patients after unsuccessful femoral artery cannulation. This demonstrates that repeated attempts at femoral artery catheterization may increase the incidence of perfusion-related complications. Absent pedal pulse associated with femoral artery catheterization occurred in only three patients and the data do suggest that the incidence of perfusion-related complications is low with the 2F catheter in neonates. All patients were treated with pentoxifylline for absent pedal pulses, without catheter removal. Resolution of absent and discrepant pulses occurred in all patients within 6 hours after procedure.

In this study, we cannulated all neonates in the ICU before cardiac surgery or catheter intervention. In all catheter interventions, we exchanged 2F catheter to 4F or 5F arterial sheath in the cardiac catheterization laboratory. However, it is difficult to exchange an 2F catheter for a 4F or 5F arterial sheath in the same femoral artery in neonates because a 0.025-inch guidewire cannot pass the 2F guidewire lumen (0.019-inch size). Therefore, the 2F catheter needs to be removed over its original 0.019-inch 22 cm straight guidewire, and then 20-gauge angiocath without introducer needle (0.025-inch inner dimension) is advanced over the 0.019-inch guidewire. Then, 0.019-inch guidewire needs to be exchanged for a 0.025-inch guidewire to introduce a 4F or 5F arterial sheath

Although this study is limited by the fact that it reflects the experience of a single institution and single operator inserting the catheters, it is empowered by a significant number of patients that, as far as we are aware, represents the largest published series.

Seldicath 2F catheter system includes 22-gauge introducer needle, 0.019-inch straight guidewire, and polyurethane 2F catheter 4 cm in length. The additional cost of 0.014-inch floppy guidewire over 2F catheter system is insignificant when compared with the overall cost of 2F catheter. The cost of a 0.014-inch floppy guidewire available on the market ranges from $30 to $50 dollars while the cost of a 2F catheter system is around $40. In fact, it may result in lower cost if it assists to minimize the complication rates in the high-risk population.

In conclusion, the use of ultrasonography guidance with 0.014-inch floppy guidewire for the cannulation of the femoral artery in particularly very small neonates undergoing cardiac surgery or cardiac intervention reduces the time to attempt femoral artery cannulation, and the total number of attempts at arterial cannulation, and increases the number of successful cannulations on first attempt compared with the ultrasonography guidance with 0.019-inch straight guidewire.

REFERENCES

1. Gallagher JD, Moore RA, McNicholas KW, et al: Comparison of radial and femoral arterial blood pressures in children after cardiopulmonary bypass. *J Clin Monit* 1985; 1:168–171
2. Chauhan S, Saxena N, Mehrotra S, et al: Femoral artery pressures are more reliable than radial artery pressures on initiation of cardiopulmonary bypass. *J Cardiothorac Vasc Anesth* 2000; 14:274–276
3. Dorman T, Breslow MJ, Lipsett PA, et al: Radial artery pressure monitoring underestimates central arterial pressure during vasopressor therapy in critically ill surgical patients. *Crit Care Med* 1998; 26:1646–1649
4. Asheim P, Mostad U, Aadahl P: Ultrasound-guided central venous cannulation in infants and children. *Acta Anaesthesiol Scand* 2002; 46:390–392
5. Breschan C, Jost R, Platzer M, et al: Nitinol mandril guide wire facilitates percutaneous subclavian vein cannulation in a very small preterm infant. *Paediatr Anaesth* 2006; 16:366–368

6. Tóth GG, Yamane M, Heyndrickx GR: How to select a guidewire: Technical features and key characteristics. *Heart* 2015; 101:645–652
7. Machotta A, Kerner S, Höhne C, et al: Ultrasound-guided central venous cannulation in a very small preterm neonate. *Paediatr Anaesth* 2005; 15:325–327
8. Lim ST, Koh TH: Guide catheters and wires. *In*: Percutaneous Interventional Cardiovascular Medicine: The EAPCI Textbook. Vol. II. Eeckhout E, Serruys PW, Wijns W, et al (Eds). Toulouse, PCR Publishing, 2012, pp 33–34
9. Erglis A: Coronary guidewires. *EuroIntervention* 2010; 6:168–169
10. Aouad MT, Kanazi GE, Abdallah FW, et al: Femoral vein cannulation performed by residents: A comparison between ultrasound-guided and landmark technique in infants and children undergoing cardiac surgery. *Anesth Analg* 2010; 111:724–728
11. Siddik-Sayyid SM, Aouad MT, Ibrahim MH, et al: Femoral arterial cannulation performed by residents: A comparison between ultrasound-guided and palpation technique in infants and children undergoing cardiac surgery. *Paediatr Anaesth* 2016; 26:823–830
12. Troianos CA, Hartman GS, Glas KE, et al; Councils on Intraoperative Echocardiography and Vascular Ultrasound of the American Society of Echocardiography; Society of Cardiovascular Anesthesiologists: Special articles: Guidelines for performing ultrasound guided vascular cannulation: Recommendations of the American Society of Echocardiography and the Society Of Cardiovascular Anesthesiologists. *Anesth Analg* 2012; 114:46–72