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SHORT COMMUNICATION

Time-consumption risk of real-time ultrasound-guided internal jugular vein cannulation in pediatric patients: comparison with two conventional techniques

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Abstract To assess the efficacy of three different methods for internal jugular vein (IJV) cannulation in pediatric patients, we conducted a review of patients undergoing cardiovascular surgery over an 11-year period, in which success rates for cannulation and time from induction of anesthesia to cannulation were evaluated. The success rate was better for real-time ultrasound guidance (USG: 90%) than for anatomic landmarks (AL: 76%) or audio-Doppler guidance (ADG: 74%) and the time required was greater for USG (35.0 ± 13.6 min) than for AL (26.7 ± 11.2 min) or ADG (29.2 ± 8.9 min). However, USG resulted in a higher success rate than the other methods with comparable procedure time for smaller-body-weight (<5 kg) patients. Thus real-time USG leads to the highest success rate for IJV cannulation but with a significant time delay, whereas it was the most useful without time delay for the smaller-body-weight subgroup.

Keywords Ultrasound-guidance · Pediatric · Internal jugular vein cannulation

In pediatric patients, central venous cannulation is often necessary for optimum anesthetic and postoperative management. However, cannulation based on anatomic landmarks (AL) is not always easy and sometimes leads to higher failure rates with complications [1]. Real-time ultrasound guidance (USG) for internal jugular vein (IJV) cannulation has been recognized as a safer and more successful method for children and infants [2, 3]. However, according to a recent survey of cardiac anesthesiologists [4], real-time use of ultrasound during central venous cannulation was still limited, and one reason given for not using ultrasound was possible time delay. Previous reports revealed that USG improved the time spent on cannulation itself [5–7], and there is no information about whether USG could cause time delay because of other variable factors including preparing the ultrasound machine, positioning, and scanning before cannulation. Therefore, the objective of this retrospective study was to evaluate success rates and time from induction of anesthesia to real-time USG for IJV cannulation in pediatric patients compared with two conventional methods: AL and audio-Doppler guidance (ADG).

With the approval of our University ethical committee, a retrospective medical records review was conducted on patients aged less than 7 years receiving general anesthesia for cardiovascular surgery at Hirosaki University Hospital between January 1, 1997 and December 31, 2007. We included pediatric patients who required central venous cannulation in the operating room. A successful cannulation was defined as right IJV catheterization, because it has been our first-choice vein for central venous cannulation for pediatric patients undergoing cardiovascular surgery in our hospital. Catheterizations into other veins, for example a femoral vein, were defined as failure. The time spent from induction of anesthesia to the end of IJV cannulation was calculated in cases of successful cannulation. The operator performing IJV cannulation was defined as an anesthesiologist listed initially in each anesthesia record.

Patients were allocated to three groups according to the year when they underwent general anesthesia, because we introduced skin surface marking with ADG in 2000, and

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real-time USG in 2004; AL group in 1997–1999, ADG group in 2001–2003, USG group in 2005–2007. We excluded patients receiving general anesthesia during transition periods of these methods, 2000 and 2004. We also allocated patients to subgroups according to their body weight (<5 and ≥5 kg).

In the AL group, the carotid pulse was located at the midpoint between the mastoid process and the sternal notch, and after a sterile procedure the needle was inserted just lateral to the pulse and directed on a parallel with the carotid artery. In the ADG group, as reported previously [8], the Doppler probe was placed on the neck around the 6th cervical vertebra and was moved laterally to identify the low-pitched venous hum of IJV, and the course of the vein was mapped. After a sterile procedure the puncture was started. In the USG group, skin surface marking of IJV was done under ultrasound image to determine the best position for the ultrasound probe. After a sterile procedure the cannulation was guided using a real-time ultrasound image on the marking.

Data were expressed as means ± SD. Where appropriate, statistical analysis was performed using the chi-squared test, one way ANOVA, or the Kruskal–Wallis test followed by Fisher's exact test, Newman–Keuls test, or Dunn's test. $P < 0.05$ was considered significant.

There was no significant difference between the three methods in age and body weight (Table 1). The operators in all cases were Japanese Society of Anesthesiologists-Qualified Anesthesiologists. The cannulation success rate using the USG was significantly higher than those with the other methods (AL, 42/55; ADG, 49/66; USG, 91/101; succeeded/total number of patients), which was remarkable for patients weighing <5 kg (AL, 6/15; ADG, 5/16; USG, 27/35). However, the success rate for patients weighing ≥5 kg was comparable (AL, 36/40; ADG, 44/50; USG, 64/66). In contrast, USG required significantly more time from induction of anesthesia to the end of IJV cannulation compared with the other methods, which was seen at any body weight although the time delay failed to reach a significant difference in the <5 kg subgroup (Table 2).

In this retrospective study, we found that the success rate of IJV cannulation was improved using real-time USG (90%) compared with traditional AL (76%) or ADG (74%). Similarly, Verghese and colleagues [7] reported that success rates of IJV cannulation with AL, real-time ADG needle, and real-time USG in infants less than 12 months of age were 81, 77, and 94%, respectively. Arai and Yamashita [9] also reported that the success rate with ADG or USG was 79 or 92%, respectively. The success rate with AL or ADG in infants less than 2 kg is empirically very low. We often experience with this size infant that the blood cannot be aspirated through puncture needle from the IJV, even if the tip of the needle is in the vein, because negative pressure by aspiration may block the needle tip with the vessel wall. In this case, when the ultrasound image confirms that the tip of the needle is in the vein, insertion of a wire through the needle to the vein followed by placement of a catheter using the wire can be performed. However, this cannot be done with AL, ADG, and skin surface marking with USG. Indeed, Hosokawa and colleagues [5] found that the success rate (100%) with real-time USG was higher than that with skin surface marking with USG (89%) in infants of less than 7.5 kg. Thus, real-time USG may lead to the best success rate.

Despite the improvement in success rate, this study suggests that the USG resulted in a time delay to perform cannulation, which was one of the reasons for the limited

Table 1 Age and body weight in three groups of pediatric patients using three techniques: anatomic landmark, audio-Doppler guidance, and real-time ultrasound guidance

	Total	<5 kg	≥5 kg
AL			
Age (months)	25.9 ± 22.3	3.5 ± 4.1	34.2 ± 20.4
Weight (kg)	10.4 ± 6.1	3.5 ± 0.8	13.0 ± 5.0
ADG			
Age (months)	27.8 ± 24.1	2.0 ± 1.8	36.0 ± 21.9
Weight (kg)	10.5 ± 5.8	3.5 ± 0.5	12.8 ± 4.9
USG			
Age (months)	20.4 ± 21.0	3.4 ± 4.1	29.3 ± 20.9
Weight (kg)	8.7 ± 5.0	3.5 ± 0.8	11.4 ± 4.1

Values are mean ± SD

AL anatomic landmark, *ADG* audio-Doppler guidance, *USG* real-time ultrasound guidance

Table 2 Success rate and time spent from induction of anesthesia to central venous cannulation

	Total	<5 kg	≥5 kg
AL			
Success rate	76% (42/55)	40% (6/15)	90% (36/40)
Time (min)	26.7 ± 11.2	35.2 ± 18.7	25.3 ± 9.1
ADG			
Success rate	74% (49/66)	31% (5/16)	88% (44/50)
Time (min)	29.2 ± 8.9	30.2 ± 6.9	29.1 ± 9.1
USG			
Success rate	90% (91/101)$^{*,\#\#}$	77% (27/35)$^{*,\#\#}$	97% (64/66)
Time (min)	35.0 ± 13.6$^{**,\#}$	39.6 ± 17.2	33.1 ± 11.3$^{**,\#}$

Success rate, 100 × (succeeded/total number of patients); Time, time spent from induction of anesthesia to finishing central venous cannulation; Values are mean ± SD

AL anatomic landmark, *ADG* audio-Doppler guidance, *USG* real-time ultrasound guidance

* $P < 0.05$, ** $P < 0.01$ versus AL; $^{\#}P < 0.05$, $^{\#\#}P < 0.01$ versus ADG

use of USG revealed in a survey of USG during central venous catheterization [4]. Verghese and colleagues [6, 7] reported that the cannulation time with USG was significantly shorter than that with AL or ADG. The discrepancy may be because of differences in the time measured for cannulation between this study and the reports by Verghese et al. [6, 7]. They measured the time from initial needle insertion to the end of cannulation whereas we measured from the induction of anesthesia to the end of cannulation. However, in the <5 kg subgroup, the time delay did not reach significance. USG resulted in the highest success rate compared with the other methods with similar procedure time in smaller body weight patients.

Our results indicate that the IJV cannulation with USG can cause time delay. However, the time spent from induction of anesthesia to the end of IJV cannulation should contain many variables, although the time measured in this study could include the time for subsequent steps—neck and body positioning and thorough pre-puncture screening, the importance of which has been demonstrated in the central venous cannulation with USG in infants and children [3, 10, 11]. Further studies are needed to evaluate the time-consuming effect of these pre-puncture steps.

In conclusion, this study indicates that the real-time USG led to a significantly higher success rate but with an increased delay compared with conventional methods. However, USG resulted in the highest success rate with comparable procedure time in smaller-body-weight patients.

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