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Sheath placement in femoral artery during cardiac catheterization in children can influence pressure waveform

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ABSTRACT

Introduction: It is reported that pressure wave reflection is enhanced by external compression of the femoral artery. Therefore, it is possible that cardiac catheterization itself can influence the aortic pressure waveform.
Aim: The purpose of this study is to clarify the influence of sheath placement in a femoral artery on the pressure waveform.
Methods: This study enrolled 21 pediatric patients (5.1 ± 4.0 years) who underwent cardiac catheterization. A sheath was placed in the femoral arteries of all patients. The change in the pressure waveform induced by the placement of the sheath was investigated using the b/a and d/a ratio of second derivative of a fingertip photoplethysmogram. A high b/a ratio means a stiff aorta and a low d/a ratio represents an enhancement of the aortic pressure wave reflection.
Results: By the placement of the sheath in their femoral arteries, the b/a ratio was not influenced (sheath (−): −0.556 ± 0.081 vs. sheath (+): −0.558 ± 0.072; $p = 0.896$). However, the d/a ratio was significantly decreased (−0.150 ± 0.074 vs. −0.185 ± 0.084; $p = 0.0003$).
Conclusions: The placement of the femoral arterial sheath enhances the pressure wave reflection and would lead to a change in the central aortic pressure waveform.

1. Introduction

Analysis of pressure waveform obtained by cardiac catheterization is still the gold standard for analysis of vascular characteristics [1], although non-invasive pulse wave analysis has been emerging for evaluation of vascular damage. Murgo and colleagues reported that aortic pressure augmentation by the enhancement of aortic pressure wave reflection occurred by external compression of the femoral arteries [2]. This means that the placement of a sheath in the femoral artery for cardiac catheterization could possiblyenhance the pressure wave reflection. However, there is no report about changes in aortic pressure augmentation following cardiac catheterization itself. The purpose of this study is to clarify the influence of sheath placement in a femoral artery on the aortic pressure waveform.

2. Methods

2.1. Study subjects

This study enrolled 21 pediatric patients aged 1–18 years (5.1 ± 4.0 years) who underwent a cardiac catheterization in order to evaluate the hemodynamics of congenital heart disease in Chiba Children's Hospital between November 2015 and April 2016 (Table 1). Patients under 10 kg body weight were excluded, because the photoplethysmogram (PTG) sensor was too large for such small children to measure the PTG.

2.2. Study design (measurements)

All patients received a sheath in their femoral arteries for left-heart cardiac catheterization. The sizes of the sheath were 4F in 17 and 5F in 4. Just before and after the sheath placement, a PTG was recorded using a digital fingertip PTG (SDP-100, Fukuda Denshi, Tokyo, Japan) in all patients. The sensor of the SDP-100 was located at the cuticle on the second digit of the right hand in patients with left aortic arch and in the left hand in patients with right aortic arch. The mechanism measuring the PTG in SDP-100 was almost identical with that in FCP-4731 [3]. The SDP-100 records pulse waves for 5 s and analyzes the averaged wave. We assessed second derivative of the fingertip PTG (SDPTG), which has been verified as a useful non-invasive method for pulse wave analysis, and calculated b/a and d/a ratio based on the height of the pulse wave components [4]. The b/a ratio means the arterial stiffness and the d/a ratio represents the degree of the pressure wave reflection. That is to say, a high b/a ratio means a stiff aorta and a low d/a ratio represents an enhancement of the aortic pressure wave reflection. All measurements were performed when the subjects were resting in the supine position and under sedation for the cardiac catheterization. Concerning the patients who underwent general anesthesia (5 patients), propofol, fentanyl, remifentanil and sevoflurane were administered for anesthesia. Regarding the patients who underwent intravenous sedation (16 patients), midazolam, ketamine and pethidine were administered for sedation as required. The first measurement of the SDPTG was performed subsequent to administration of the anesthetic/sedative drugs. Immediately after the prompt placement of the femoral arterial sheath, the SDPTG was re-evaluated. The change in the SDPTG induced by the

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Table 1
Patients' profile.

	$n = 21$
Gender (M/F)	15/6
Age (years)	5.1 ± 4.0
Height (cm)	99.4 ± 20.2
Weight (kg)	16.0 ± 9.8
Body mass index (kg/m^2)	15.3 ± 1.5

Data are given as mean ± SD.

placement of the sheath was investigated. We analyzed b/a ratio, d/a ratio and delta d/a ratio, which was defined as the d/a after minus before the sheath placement.

The ethics committee of Chiba Children's Hospital approved this study protocol.

2.3. Statistical analysis

All data were presented as mean ± standard deviation. Comparisons between parameters before and after sheath placement were performed by paired *t* analysis. The relationships between the delta d/a ratio and the patient's age and height were examined. Comparison between the delta d/a ratio in patients less than and above 100 cm in height was performed by Mann–Whitney *U* test. A p value <0.05 was considered statistically significant.

3. Results

The demographic data of the subjects are given in Table 1. Fig. 1 shows the change of the SDPTG waveform just before and after the placement of the sheath in a femoral artery. It demonstrates the decrease of the d wave after the placement of the sheath. The heart rate and brachial cuff blood pressure (systolic, diastolic and pulse pressure) did not change significantly (Table 2). By placement of the sheath in the femoral artery, the b/a ratio was not influenced (−0.556 ± 0.081 vs. −0.558 ± 0.072; $p = 0.896$). However, the procedure significantly reduced the d/a ratio (−0.150 ± 0.074 vs. −0.185 ± 0.084; $p = 0.0003$) (Fig. 2). There was a positive relationship between the delta d/a ratio and the patient's growth (age; $r = 0.25$ $p = 0.28$ and height; $r = 0.39$ $p = 0.08$), though the relationship was not statistically significant. The change of the d/a by the sheath placement in patients <100 cm in height is significantly larger than that in patients above 100 cm in height (Fig. 3).

4. Discussion

The present study demonstrates that the aortic pressure wave reflection is enhanced by the placement of the sheath in femoral artery for cardiac catheterization. The aortic pressure augmentation caused by pressure wave reflection is a physiologically important phenomenon. It maintains constant arterial blood flow and enhances coronary blood supply [1,5]. However, it is reported that excessive aortic pressure wave reflection is one of the risk factors for developing cardiovascular disease [6,7].

Murgo and colleagues [2] examined the ascending aortic pressure waveform during bilateral external compression of the femoral arteries. They noted that "the end-diastolic pressure and the pressure at the reflection point do not change significantly, but the late systolic portion of the ascending aortic waveform immediately increases". It means the enhancement of the pressure wave reflection. Moreover, it is also reported that squatting, which would compress the femoral arteries, also caused an augmentation of the reflection pressure wave [8].

The SDPTG has been developed to allow a more accurate recognition of the inflection points on the original PTG wave [3,4,9]. It consists of five waves, labeled a–e, although the clinical significance of the c and e waves has not been fully clarified. Takazawa and colleagues reported the significances of the b and d waves [3]. The b wave is included in

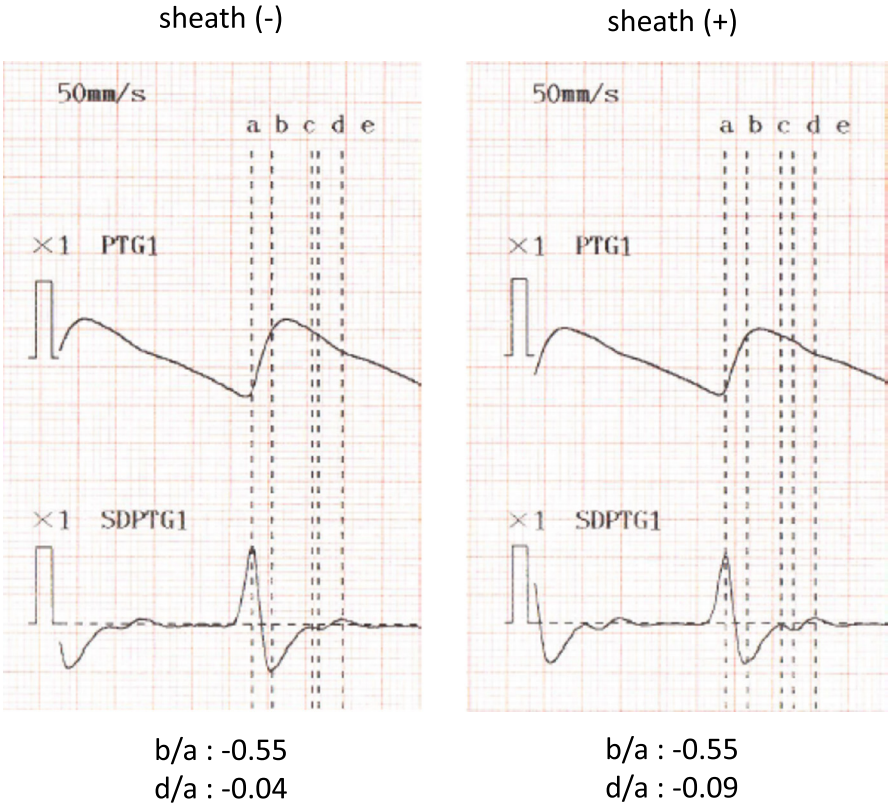

Fig. 1. Difference in the second derivative of the fingertip photoplethysmogram waveform before and after placement of a sheath. A 2-year-old, body height 81 cm, body weight 10.5 kg, body mass index 16.0 kg/m^2. The d wave decreased after the placement of the sheath. PTG, photoplethysmogram; SDPTG, second derivative of the fingertip photoplethysmogram.

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