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ORIGINAL RESEARCH

Evaluation of the relationship between the topographical anatomy in the axillary region of the brachial plexus and the body mass index

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Abstract To investigate the topographic anatomy of the median, musculocutaneous, radial and ulnar nerves with respect to the axillary artery and to seek whether these configurations are associated with baseline descriptive data including age, gender, and body-mass index. This cross-sectional trial was carried out on 199 patients (85 women, 114 men; average age: 46.78 ± 15.45 years) in the department of anaesthesiology and reanimation of a tertiary care center. Topographic anatomy of the median, musculocutaneous, radial and ulnar nerves was assessed with ultrasonography. Localization of these nerves with respect to the axillary artery was marked on the map demonstrating 16 zones around the axillary artery. Frequencies of localizations of every nerve in these zones were recorded, and the correlation of these locations with descriptive data including age, gender and BMI was investigated. There was no difference between women and men for the distribution of the median ($p = 0.74$), ulnar ($p = 0.35$) and radial ($p = 0.64$) nerves. However, the musculocutaneous nerve was more commonly located in Zone A13 in men compared to women ($p = 0.02$). The localization of the median ($p = 0.85$), ulnar ($p = 0.27$) and radial ($p = 0.88$) nerves did not differ remarkably between patients with BMI < 25 kg/m^2 and patients with BMI ≥ 25 kg/m^2. Notably, the musculocutaneous nerve was more often determined in Zone A10 in cases with BMI ≥ 25 kg/m^2 ($p = 0.001$). Our results imply that the alignment of the musculocutaneous nerve may vary in men and overweight people. This fact must be considered by the anaesthetist before planning the axillary block of brachial plexus. All these informations may enlighten the planning stages of the brachial plexus blockade.

Keywords Brachial plexus · Nerve · Axillary block · Anatomy · Musculocutaneous nerve · Bodymass index

1 Introduction

When compared with general anaesthesia for surgery of the upper extremity, regional anaesthesia offers many advantages such as more effective control of pain, decreased need for systemic opioids, better range of motion following interventions and enhancement of early discharge after ambulatory procedures [1]. Blockade of the axillary brachial plexus is a common method in regional anaesthesia [2]. This approach allows the separate blockade of the four main constituent nerves, the radial, median, ulnar and musculocutaneous nerves, safely and successfully [3]. Effective analgesia by means of this method necessitates a thorough understanding of the brachial plexus anatomy. For this purpose, high-definition ultrasound has been commonly used [4]. The relationship between the axillary artery and the brachial plexus is an important landmark for appropriate identification of the target nerves and safely guidance of needle.

The brachial plexus nerves are placed within a neurovascular sheath surrounding the axillary artery, but the position of the nerves inside the sheath is variable and permits a certain extent of movement [5]. Previous publications

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indicated that the position of the upper extremity can influence the configuration of nerves and anatomical landmarks [3]. Unpredictable localization and variations of the brachial plexus nerves can sometimes be challenging for an effective brachial plexus blockade [1, 3]. In this context, the relationship between the anatomical configuration of the brachial plexus nerves and anthropometric data such as age, gender and body-mass index (BMI) may provide useful clues.

The aim of the present study was to investigate the topographic anatomy of the median, musculocutaneous, radial and ulnar nerves with respect to the axillary artery and to seek whether these configurations are associated with baseline descriptive data including age, gender, and BMI.

2 Methods

2.1 Study design

This cross-sectional trial was carried out in the department of anaesthesiology and reanimation of a tertiary care unit. The study was approved by the Ethics Committees of the University of Kafkas (protocol number: 2015/08) and written informed consent from every participant were obtained before the study.

One hundred ninety-nine patients (85 women, 114 men) planned for axillary brachial plexus blockade were included. Demographic data including age, gender and BMI were recorded. Exclusion criteria consisted of a refusal to participate in the study, history of infection, trauma or surgery in the axillary region and restriction in shoulder movement. Patients in whom two or more nerves could not be identified with ultrasound imaging, were also excluded from the analysis.

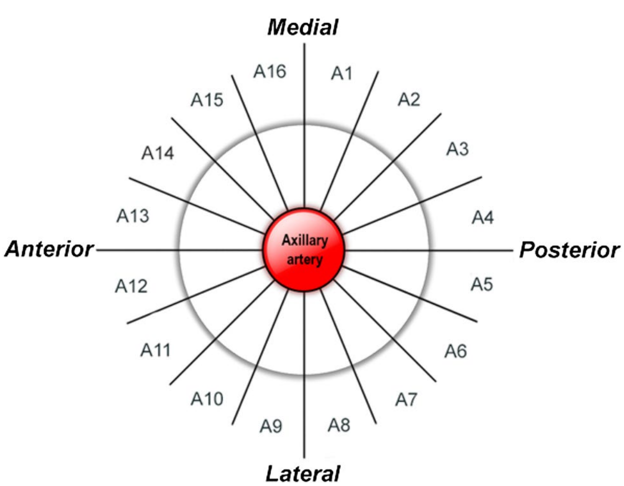

Fig. 1 Cross-sectional ultrasonography images were obtained with an ultrasound probe placed on the axillary fossa. The map was used to mark the localizations of the median, musculocutaneous, ulnar and radial nerves according to the axillar artery. Sixteen zone (A1–A16) were defined for alignment of these nerves. *AA* axillary artery

2.2 Ultrasonographic measurement

In the present study, a portable ultrasound device (UGEO HM70ATM, Samsung, Seoul, Korea) and a 10–18 MHz linear multifrequency probe was used. Patients were in the supine position, and ultrasonographic measurement of the topographic anatomy of the median, musculocutaneous, radial and ulnar nerves was made. Localization of these nerves with respect to the axillary artery was marked on the map as shown in Fig. 1 [6].

After the optimization of the depth and gain, 'resolution mode' was selected at the ultrasound device. The probe was applied with light pressure in order to collapse the main veins surrounding the axillary artery without deforming the anatomic structures. The ultrasound beam was set perpendicular to the brachial plexus nerves and the axillary artery. Therefore, they appeared as round or oval structures in short axis view on the ultrasound scan.

Table 1 Distribution of brachial plexus nerves in 16 zones around the axillary artery in our study population (n = 199)

Nerve	Zone	n (%)
Median	A1	23 (11.5)
	A2	7 (3.5)
	A13	2 (1.0)
	A14	7 (3.5)
	A15	65 (32.5)
	A16	95 (47.5)
Ulnar	A1	17 (8.5)
	A2	41 (20.5)
	A3	60 (30)
	A4	56 (28)
	A5	22 (11)
	A6	3 (1.5)
Radial	A5	7 (3.5)
	A6	20 (10)
	A7	67 (33.5)
	A8	71 (35.5)
	A9	30 (15)
	A10	4 (2)
Musculocutaneous	A9	2 (1)
	A10	35 (17.5)
	A11	75 (37.5)
	A12	70 (35)
	A13	16 (8.0)
	A14	1 (0.5)

The arm was placed in a position with the arm at an abduction of 90° and flexion of the elbow at 90°. The proximal level, which was defined as the intersection point between the lower border of the pectoralis major muscle and the biceps brachii muscle, was used for imaging [7].

A BMI <25 kg/m^2 was addressed as normal or underweight, while a BMI equal to or >25 kg/m^2 was considered as overweight or obese [8]. Therefore, we accepted 25 kg/m^2 as the cut-off point for BMI.

The distributions of the median, musculocutaneous, ulnar and radial nerves were noted in the 16 zones around the axillary artery. Correlation between BMI, age, and localization of these nerves was sought.

2.3 Statistical analysis

Analysis of data was performed via IBM Statistical Package for Social Sciences (SPSS) Statistics 20 software (SPSS Inc., Chicago, IL, USA). Normality of distribution for variables was tested via Kolmogorov–Smirnov test. Categorical variables were compared using Pearson Chi-Square test. Kruskal–Wallis test was performed for comparison of independent groups. The confidence interval was 95% and a p value <0.05 was considered as statistically significant.

3 Results

Our series consisted of 114 men and 85 women with an average age of 46.78 ± 15.45 (range 18–85). The average BMI was 27.21 ± 4.37 (range 17.6–43.5) kg/m^2.

Ultrasonography demonstrated that the median nerve was most frequently detected in Zone A16 (n = 95, 47.5%), Zone A15 (n = 65, 32.5%) and Zone A1 (n = 23, 11.5%). The ulnar nerve was more commonly visualized in Zone A3 (n = 60, 30%), Zone A4 (n = 56, 28%), Zone A2 (n = 41, 20.5%) and Zone A5 (n = 22, 11%). The radial nerve was more commonly observed in Zone A8 (n = 71, 35.5%), Zone A7 (n = 67, 33.5%), Zone A9 (n = 30, 15%) and Zone A6 (n = 20, 10%). The musculocutaneous nerve was most often detected in Zone A11 (n = 75, 37.5%), Zone A12 (n = 70, 35%) and Zone A10 (n = 35, 17.5%). Table 1 presents the distribution of the nerve localizations in the 16 zones as demonstrated in Fig. 1.

Table 2 Alignment of the median, ulnar, radial and musculocutaneous nerves in different gender and body-mass index groups

Nerve	Zone	Gender		p value	Body-mass index (kg/m^2)		p value
		Men n (%)	Women n (%)		<25 n (%)	≥25 n (%)	
Median	A1	12 (10.5)	11 (12.9)	0.74	7 (12.7)	16 (11.1)	0.85
	A2	4 (3.5)	3 (3.5)		3 (5.5)	4 (2.8)	
	A13	2 (1.8)	0 (0)		0 (0)	2 (1.4)	
	A14	3 (2.6)	4 (4.7)		2 (3.6)	5 (3.5)	
	A15	36 (31.6)	29 (34.1)		19 (34.5)	46 (31.9)	
	A16	57 (50)	38 (44.7)		24 (43.6)	71 (49.3)	
Ulnar	A1	9 (7.9)	8 (9.4)	0.35	8 (14.5)	9 (6.3)	0.27
	A2	18 (15.8)	23 (27.1)		9 (16.4)	32 (22.2)	
	A3	39 (34.2)	21 (24.7)		15 (27.3)	45 (31.3)	
	A4	34 (29.8)	22 (25.9)		15 (27.3)	41 (28.5)	
	A5	13 (11.4)	9 (10.6)		6 (10.9)	16 (11.1)	
	A6	1 (0.9)	2 (2.4)		2 (3.6)	1 (0.7)	
Radial	A5	2 (1.8)	5 (5.9)	0.64	3 (5.5)	4 (2.8)	0.88
	A6	11 (9.6)	9 (10.6)		4 (7.3)	16 (11.1)	
	A7	39 (34.2)	28 (32.9)		17 (30.9)	50 (34.7)	
	A8	40 (35.1)	31 (36.5)		21 (38.2)	50 (34.7)	
	A9	19 (16.7)	11 (12.9)		9 (16.4)	21 (14.6)	
	A10	3 (2.6)	1 (1.2)		1 (1.8)	3 (2.1)	
Musculocutaneous	A9	1 (0.9)	1 (1.2)	0.02*	0 (0)	2 (1.4)	0.001*
	A10	16 (14.0)	19 (22.4)		2 (3.6)	33 (22.9)	
	A11	38 (33.3)	37 (43.5)		16 (29.1)	59 (41.0)	
	A12	43 (37.7)	27 (31.8)		29 (52.7)	41 (28.5)	
	A13	15 (13.2)	1 (1.2)		7 (12.7)	9 (6.3)	
	A14	1 (0.9)	0 (0)		1 (1.8)	0 (0)	

*Statistically significant

BMI body-mass index

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There was no difference between women and men for the distribution of the median (p = 0.74), ulnar (p = 0.35) and radial (p = 0.64) nerves. However, the musculocutaneous nerve was more commonly located in Zone A13 in men compared to women (p = 0.02) (Table 2).

The localization of the median (p = 0.85), ulnar (p = 0.27) and radial (p = 0.88) nerves did not differ remarkably between patients with BMI < 25 kg/m^2 and patients with BMI ≥ 25 kg/m^2. There was a significant difference between the BMI groups with respect to the alignment of the musculocutaneous nerve (p < 0.001) (Table 2) (Figs. 2, 3).

Analysis of our data has shown that age did not have a noteworthy effect on the distribution of the median (p = 0.83), ulnar (p = 0.06), radial (p = 0.46) and musculocutaneous nerves (p = 0.14).

4 Discussion

The objective of the present study was to assess the topographic anatomy of the median, musculocutaneous, radial and ulnar nerves with the axillary artery as reference. Furthermore, the correlation between the configurations of these nerves and the baseline descriptive data was sought. Our results indicated that only the alignment of the musculocutaneous nerve exhibits variability with respect to gender and BMI. The median, ulnar and radial nerves seem to have a more constant configuration with respect to age, gender and BMI.

Variations are common in the brachial plexus, which innervates the upper limb. A cadaveric study reported that only 52.3% of the subjects have a classical brachial plexus anatomy [9]. Another cadaveric study reported that the variations of the brachial plexus anatomy may be secondary to interconnecting fibers' pathway variations between scalene muscles [10]. A good anatomical knowledge is crucial for all invasive procedures that may be performed by anatomists, radiologists, anaesthesiologists and surgeons. The presence of anatomical variations of the peripheral nerve system may be used to explain unexpected clinical signs and symptoms [11]. Novel imaging methods allow improved identification of the anatomic relationships for successful nerve blockade along the brachial plexus.

Increased awareness on the impact of demographic variables such as BMI and gender can be useful in recognition of the local anatomy, demonstration of the positions of the nerves and detection of anatomic variations. This may

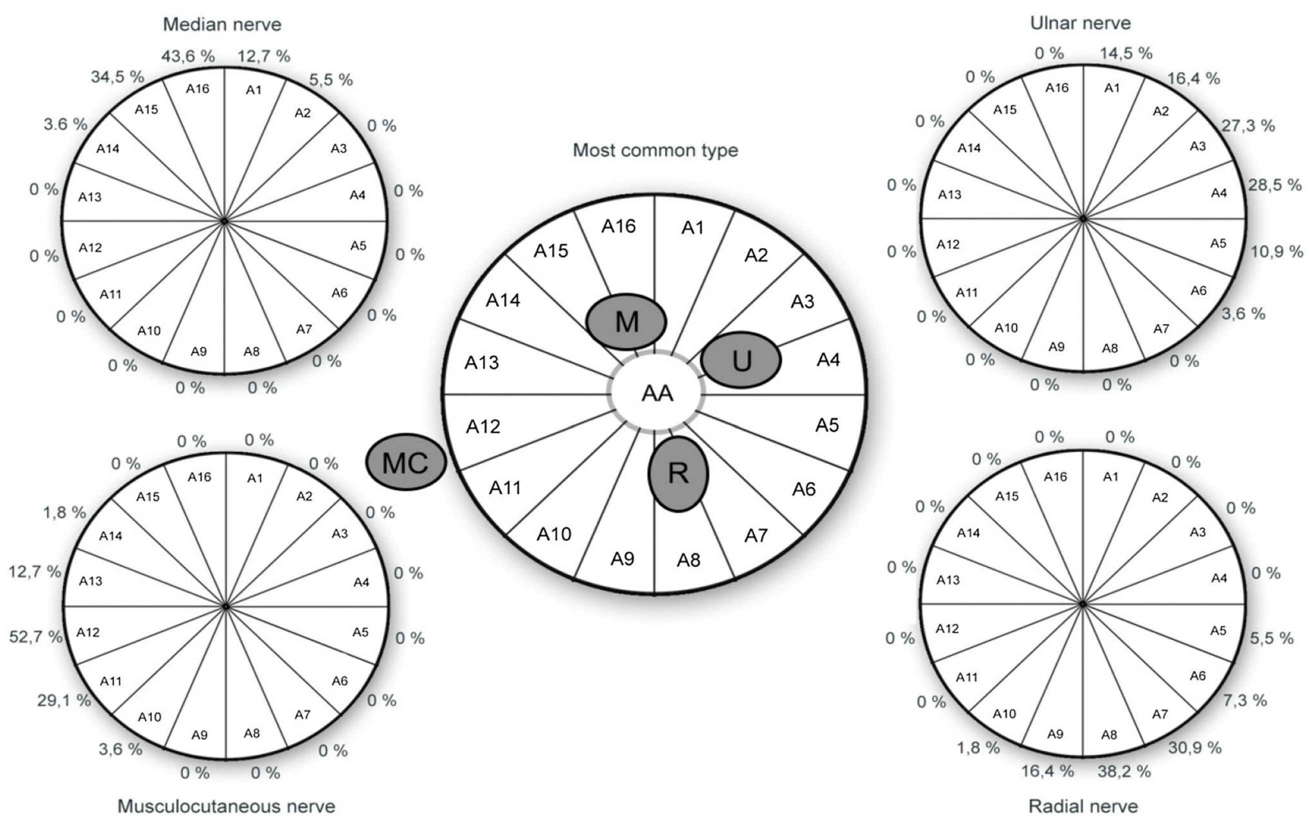

Fig. 2 The schematic presentation of the brachial plexus nerves in patients with BMI < 25 kg/m^2. *AA* axillary artery, *M* median nerve, *U* ulnar nerve, *R* radial nerve, *MC* musculocutaneous nerve

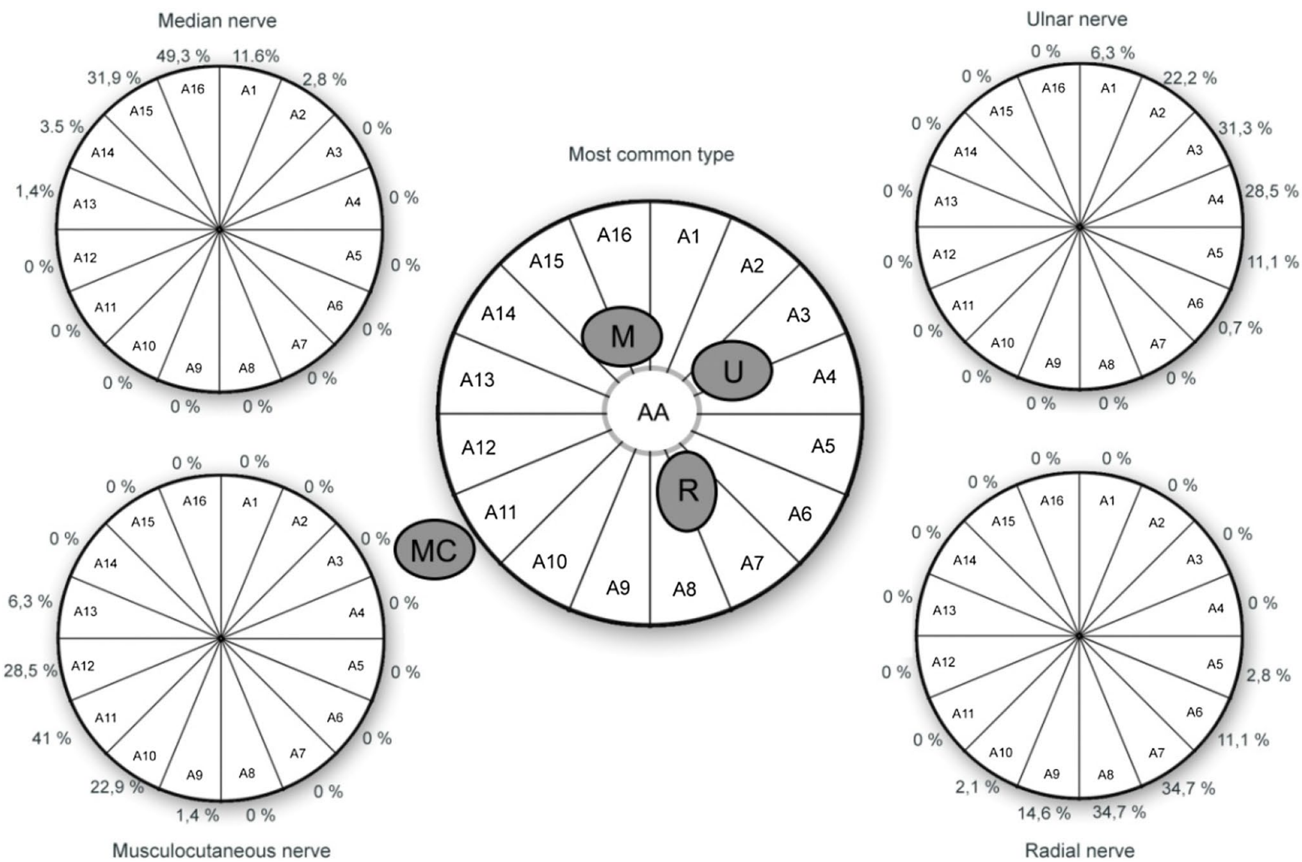

Fig. 3 The schematic presentation of the brachial plexus nerves in patients with BMI ≥ 25 kg/m^2. *AA* axillary artery, *M* median nerve, *U* ulnar nerve, *R* radial nerve, *MC* musculocutaneous nerve

interfere with the success of the block or compromise the patient safety.

The brachial plexus nerves are aligned around the axillary artery within a neurovascular sheath [7]. The results of the study showing the distribution of the brachial plexus in the axillary region and the results of our study were similar [6]. The positions of the median, musculocutaneous, ulnar and radial nerves inside the sheath may be variable. Moreover, the fibers may be exchanged between these individual nerves [12]. The variability of the anatomy in the axillary fossa can be challenging particularly for the block of single nerves that comprise the brachial plexus [13].

The axillary block is more commonly performed at the intersection point of pectoralis major and biceps brachii muscles. At this point, the radial, median and ulnar nerves are consistently found within the common neurovascular sheath. However, the musculocutaneous nerve usually separates more proximally and is usually found between the biceps brachii and coracobrachialis muscles [4]. Since the radial nerve lies deep and lateral posterior to the axillary artery, its visualization using ultrasound can be difficult [14].

To our knowledge, this is the first study focusing on the relationship between baseline descriptive data such as age, gender, BMI and the configuration of the brachial plexus nerves around the axillary artery. Our results indicated that distributions of the median, ulnar and radial nerves were not affected by gender. Notably, the alignment of the musculocutaneous nerve varied significantly between different BMI and gender groups. In contrary, age does not have any impact on the configuration of all of the terminal nerves. Relevant literature supports that the musculocutaneous nerve is commonly affected by the abnormalities involving the brachial plexus [1]. Prasada Rao et al. noted that the musculocutaneous nerve was completely absent in 8% of cadavers [15]. In addition, the musculocutaneous nerve may fuse to, or accompany, the median nerve, running distally for a variable distance before separating from it, rather than coursing into the coracobrachialis muscle in the axilla [1]. This has been reported during a case of ultrasound-guided axillary block, in which the musculocutaneous nerve was not observed in the coracobrachialis muscle [16].

Since the musculocutaneous nerve usually leaves the brachial plexus sheath shortly after the formation of the cords from which originates [17], it is more likely to be affected by variations. Consistent with our results, the median, ulnar and radial nerves were found to demonstrate a more predictable pattern around the axillary artery which can be easily recognized with ultrasonography [18].

The axillary artery is a basic landmark for ultrasound-guided axillary block [19]. An axillary approach provides a suitable extent of anaesthesia for surgical and percutaneous approaches and limits the risks of pneumothorax and phrenic nerve paresis that are associated with infra- and supraclavicular approaches [20]. We suggest that mapping of the axillary anatomy, based on the alignment of the nerves around axillary artery can be useful for identification of the nerves during axillary block procedures.

Recent literature supports our findings on the variability of the localization of the musculocutaneous nerve [21]. Claassen et al. suggest that atypical localizations of the musculocutaneous nerve must be remembered during axillary block interventions [21]. On the other hand, variations in the ulnar, axillary and radial nerves are relatively uncommon. Our data reminds that obesity and male gender may have implications on the musculocutaneous nerve anatomy. Attributed to the fact that the variations of the brachial plexus does not alter the normal functioning of the limb, the impact of demographic parameters must be kept in mind during planning surgical and anaesthesiological procedures [9]. We suggest that our data may contribute in the improvement of the success rate and decrease the complications of brachial plexus blockade.

Weaknesses of the present study include data restricted to the experience of a single institution, technical and operator related factors as well as the impact of ethnicity.

To conclude, variations of the brachial plexus are the rule rather than the exception and these variations may be associated with demographic parameters such as gender and BMI. Our results imply that the alignment of the musculocutaneous nerve may vary in male gender and overweight patients. This fact must be considered by the anaesthetist before planning an axillary block of the brachial plexus.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval The study was approved by the Ethics Committees of the University of Kafkas (Protocol Number: 2015/08).

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