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Classification of the Musculocutaneous Nerve Fetuses

Clasificación del Nervio Musculocutáneo en Fetos

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SUMMARY: The musculocutaneous nerve is a terminating branch of lateral cord of the brachial plexus and is formed from spinal roots of C5, C6 and C7. The anatomical variations of the musculocutaneous nerve (MCN) are not common, literary reports have described the different course of the MCN in the arm, however very few fetal studies have been conducted on the variations of the MCN. Therefore, the aim of this study was to describe the course of the MCN in fetuses and document variations, if any. In this study, a sample size of twenty-five fetuses were bilaterally dissected (n=50) using a stereomicroscope. The anatomy of the MCN was described using a classification system generated based on the findings of this study. Ethical clearance was obtained from Biomedical Research Ethics Committte (BE385/17). Type I (normal anatomy) of the MCN was found in 42/50 (84 %) of specimens in this study. This study found a few variations, viz. 1/50 (2 %) case of Type II (absent), 1/50 (2 %) Type III (communication between the MCN and MN, from the MN to the MCN), 4/50 (8 %) cases of Type IV (communication from the MCN to the MN) and 2/50 (4 %) cases of Type V (communication from the MCN to the MN, where the MCN does not pierce the coracobrachialis muscle). Therefore, this study provides evidence of variations of the MCN in fetuses that may help surgeons in the interpretation of abnormal innervation patterns in the arm.

KEY WORDS: Musculocutaneous nerve; Fetal study; Classification; Variations.

INTRODUCTION

The anatomical structure of the brachial plexus is a highly developed network of neural structures, extending from the lower part of the side of the neck to the axillary region. Many variations can occur due to its intricacy in relation to other anatomical structures around it, thus, providing clinical and surgical information (Radunovic *et al*., 2013).

The musculocutaneous nerve is one of the terminating branches of the brachial plexus, arising from the lateral cord, containing fibres from spinal roots of C5, C6 and C7, thereafter terminating as the lateral cutaneous nerve of the forearm (Besleaga *et al*., 2010; Moore *et al*., 2014; Standring *et al*., 2016). In its course, it pierces the coracobrachialis muscle and descends laterally between the biceps brachii and brachialis muscles, thus innervating all the muscles in the anterior compartment of the arm. However,previous literature has found that the lateral cord pierced the coracobrachialis muscle and then divided into musculocutaneous nerve and the lateral root of median nerve (Le Minor, 1989). Later, it pierces the deep fascia above the elbow, lateral to the tendon of the biceps brachii and continues as the lateral cutaneous nerve of the forearm (Standring *et al*.).

In addition, the lateral cord gives off a branch, the lateral root of the median nerve, which is one of the major causes of the variations in the musculocutaneous nerve. Literature described communications between the musculocutaneous nerve and the median nerve, which is the most common form of variation when it comes to either the musculocutaneous nerve or the median nerve (Venieratos & Anagnostopoulou, 1998; Choi *et al*., 2002; Loukas & Aqueelah, 2005; Kwolczak-McGrath *et al*., 2008). In some cases, the musculocutaneous nerve was reported as absent (Fregnani *et al*., 2008). When this variation occurs, the lateral cord continues to become the median nerve giving innervation to the muscles surrounding it, thus innervating the muscles in the anterior compartment of the arm (Fregnani *et al*.).Therefore, the aim of this study was to describe the course of the MCN in fetuses and document variations, if any.

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MATERIAL AND METHOD

The present study was conducted at the Department of Clinical Anatomy, University of KwaZulu-Natal (Westville Campus). Twenty-five formalin preserved fetuses (n=50) were bilaterally micro-dissected. The fetuses were placed in the supine position, a longitudinal incision in the anterior surface of the arm was made to expose brachial fascia and fat (Tank & Boileau Grant, 2009). This was separated and removed making the underlying muscles visible (Tank & Boileau Grant). The course of the MCN were traced through the plane of the loose connective tissue and the muscular branches of the MCN was observed to its terminal branch, lateral cutaneous nerve of the forearm (Tank & Boileau Grant). This study generated its own classification scheme consisting of five types to incorporate all the variations found in the present study including the normal anatomy of MCN (Fig. 1). Ethical clearance was obtained from Biomedical Research Ethics Committee (BE385/17).

RESULTS

This study recorded the following results:

Type I. Incidence - 42 cases (84 %). Course and Branching Pattern – the MCN followed the standard anatomical course (Fig. 2).

Type II. Incidence – 1 Case (2 %). Course and Branching Pattern- the MCN was absent. The lateral cord fused with the medial root of the MN, motor innovatory fibers of the anterior compartment of the arm originated directly from the upper part the MN. A branch from this union arose and then bifurcated to supply motor innervation to the Brachialis muscle. The lateral cutaneous nerve of the forearm was the terminating branch in this type (Fig. 3).

Type III. Incidence – 1 Case (2 %). Course and Branching Pattern- There was a communication between the MN and the MCN. This communication occurred from the MN

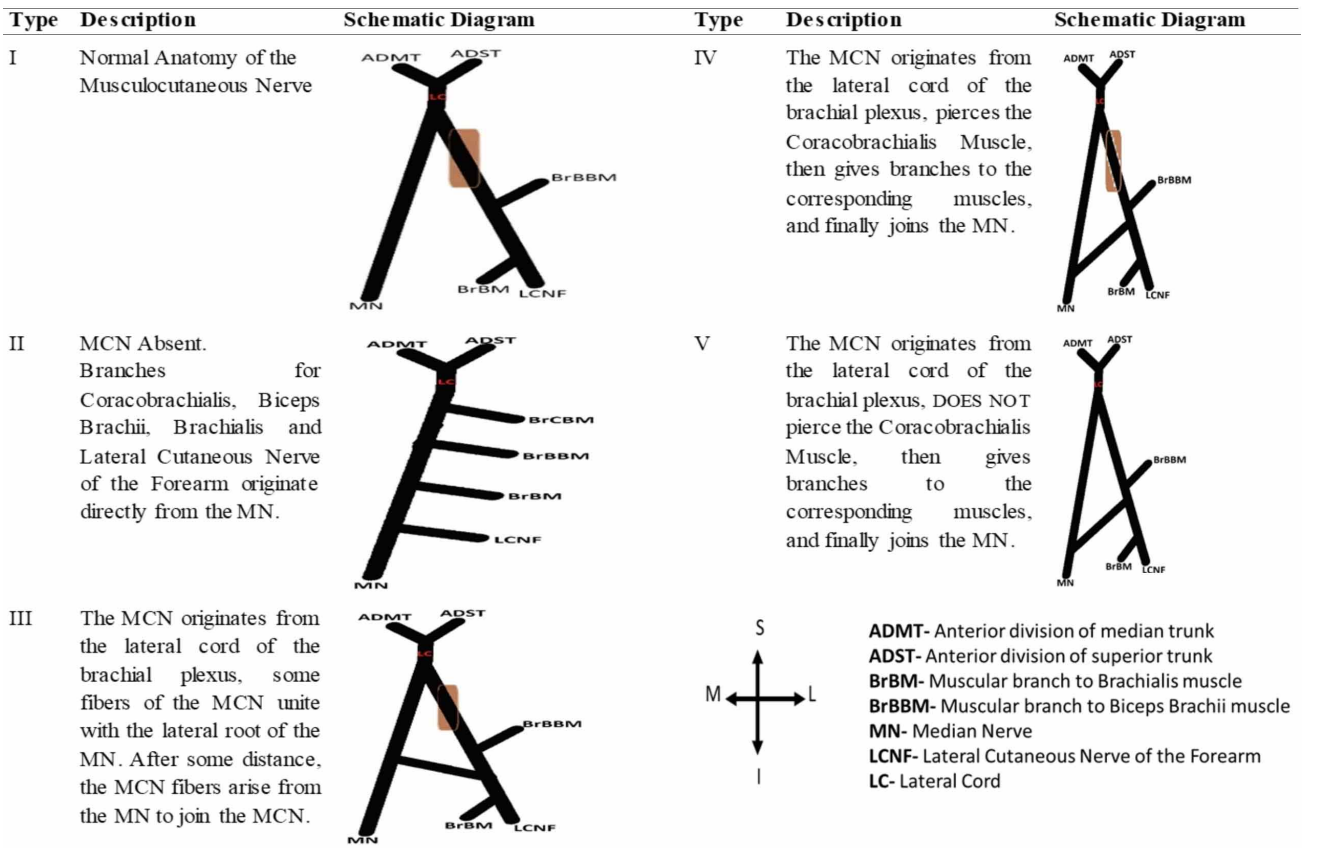

Fig. 1. Generated classification system of the course of the MCN (schema illustrating the right upper limb).

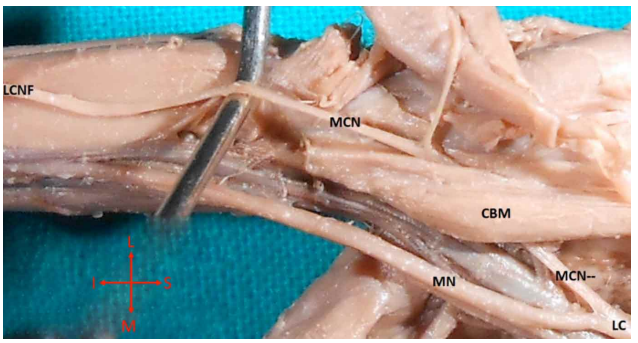

Fig. 2. Type I – Normal anatomy of right arm. MCN- MCN. CBM- Coracobrachialis muscle, LCNF- Lateral cutaneous nerve of forearm, LC- Lateral cord, MN- Median nerve, MCN- Musculocutaneous nerve, S- Superior, I- Inferior, M- Medial, L- Lateral.

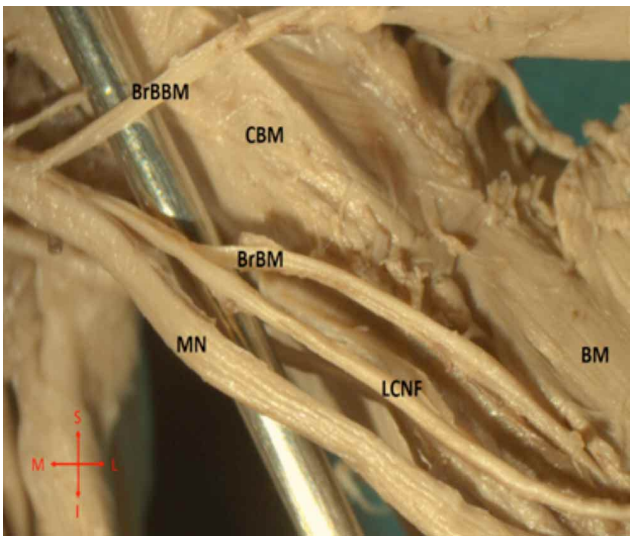

Fig. 3. Type II – Absent type. The lateral cord continued to become the MN which supplied the innervations that the MCN would have supplied. CBM- Coracobrachialis muscle, BrBBM- Muscular branch to biceps brachii muscle, BM- Brachialis muscle, BrBM- Muscular branch to brachialis muscle, LCNF- Lateral cutaneous Nerve of forearm, MN- Median nerve, S- Superior, I- Inferior, M- Medial, L- Lateral.

joining the MCN. The MCN originated from the lateral cord of the brachial plexus, some fibers of the MCN joined with the lateral root of the MN and after some distance, arose from the MN to join the MCN (Fig. 4).

Type IV. Incidence – 4 Cases (8 %) Course and Branching Pattern- A communication between the MCN and the MN, this classification is similar to type III but differed in that, the lateral root of the MN fibers, was united with the MCN and afterwards left the MCN to join back with the MN (Fig. 5). In Type IV, the MCN pierces the coracobrachialis muscle.

Type V. Incidence – 2 Cases (4 %). Course and Branching Pattern- the MCN originated from the lateral cord of the brachial plexus but did not pierce the coracobrachialis muscle it then gave branches to the biceps brachii muscle, brachialis muscle and lateral cutaneous nerve of the forearm also form a communication to the MN. This type is similar to Type IV except that in this type the MCN did not pierce the coracobrachialis muscle (Fig. 6).

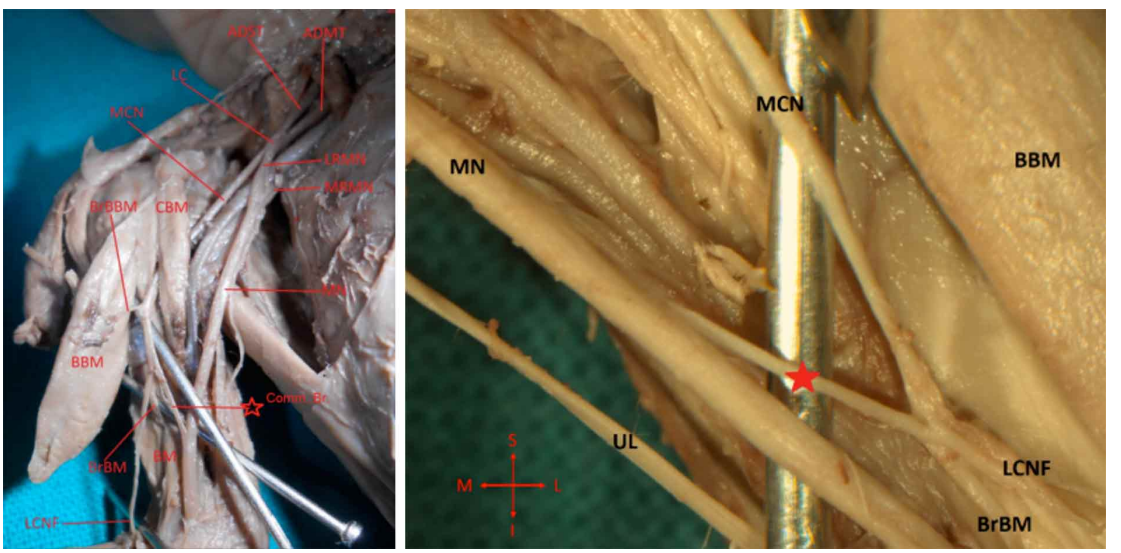

Fig. 4. TYPE III – Communicating branch from the MN to the MCN. BBM- Biceps brachii muscle, BrBM- Muscular branch to brachialis muscle, LCNF- Lateral cutaneous nerve of forearm, MN- Median nerve, MCN- Musculocutaneous nerve, UL- Ulnar nerve, S- Superior, I- Inferior, M- Medial, L- Lateral.

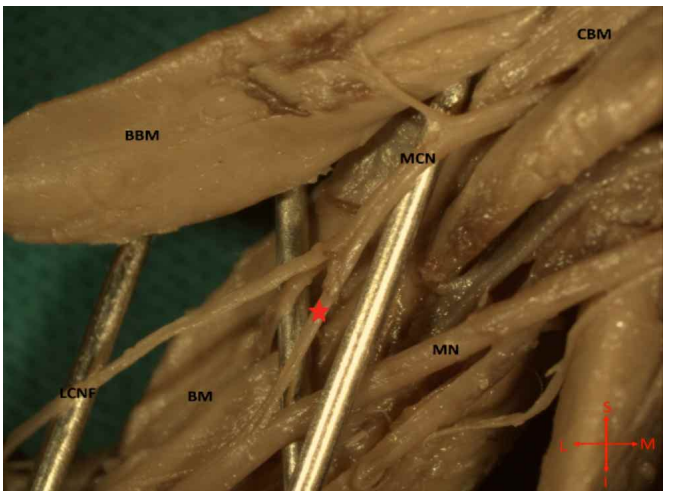

Fig.5. Type IV – Communicating branch from the MCN to the MN, MCN Pierces coracobrachialis muscle. CBM- Coracobrachialis muscle, BBM- Biceps brachii muscle, BM- Brachialis muscle, LCNF- Lateral cutaneous nerve of forearm, MN- Median nerve, MCN- Musculocutaneous nerve, S- Superior, I- Inferior, M-Medial, L- Lateral.

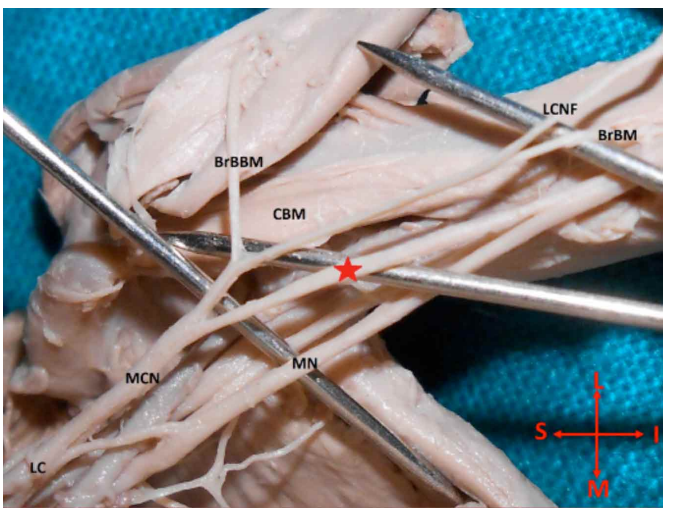

Fig. 6. Type V - Communicating branch from the MCN to the MN, MCN DOES NOT pierce Coracobrachialis muscle. CBM- Coracobrachialis muscle, BrBBM- Muscular branch to biceps brachii Muscle, BrBM- Muscular branch to brachialis muscle, LCNF- Lateral cutaneous nerve of forearm, LC- Lateral cord, MN- Median nerve, S- Superior, I- Inferior, M- Medial, L- Lateral, MCN- Musculocutaneous nerve.

DISCUSSION

The general anatomy of musculocutaneous nerve (MCN), as described by Standring *et al.*, was observed in the majority of the sample (84 %) in the present study. This correlated to literary reports, who found that the majority of their sample size followed the normal anatomical course (Le Minor; Venieratos & Anagnostopoulou; Choi *et al.*; Loukas & Aqueelah; Krishnamurthy *et al.*, 2007; Bhattarai & Poudel, 2009; Guerri-Guttenberg & Ingolotti, 2009; Uysal *et al.*, 2009; Kervancioglu *et al.*, 2011; Leng *et al.*, 2016).

The absence of the MCN (Type II) was first discovered by Le Minor in 3 cases. Venieratos & Anagnostopoulou performed a study with a sample size of 158 upper limbs and there were no cases found where the MCN was absent. However, in other studies Guerri-Guttenberg & Ingolotti found the MCN to be absent in 4 % and Leng *et al.* in 3 %, these results are similar to the present study (Table I). In addition to Type II (absence of the MCN) some authors classified this as a fusion of the MCN and MN (Chauhan & Roy, 2002; Guerri-Guttenberg & Ingolotti). Whereas, others suggested that this is a variation of the lateral cord rather than a direct variation in the MCN (Chauhan & Roy; Fazan *et al.*, 2003; Aggarwal *et al.*, 2010; Budhiraja *et al.*, 2011).

In this study, the communicating branches are the most common and this correlated with previous studies (Table I).The communicating branches are typically understood as fibers that got crossed in the lateral cord. The lateral root of the MN fibers enters the MCN and joins the MN after some distance, and vice-versa, with the fibers of the MCN entering the lateral root of the MN continuing to become the MN, and it then ultimately leaves to enter back into the MCN (Prasada Rao & Chaudhary, 2000). This was classified as Type III in the present study. In this study, Type III was found in 2 % while, Le Minor found it in 6 %,when other authors did not clearly describe if the communication was from the MN to the MCN or vice-verse. This information is vital because they are not the same as described above. Authors generalized them as the same and placed them both in the same category as a communication.

In Type IV, the coracobrachialis muscle is innervated by the MCN (Fig. 4). The occurrence of this communication between the MCN and MN was documented in literature, with the incidence ranging from 6 % to 43 %. The following percentages were documented: 6 % by Le Minor; 12 % by Venieratos & Anagnostopoulou; 19 % by Choi *et al.*; 26 % by Loukas & Aqueelah; 20 % by Chitra (2007); 6 % by Bhattarai & Poudel; 43 % by Guerri-Guttenberg & Ingolotti; 25 % by Kervancioglu *et al.* and 4 % by Leng *et al.* These findings correlated with the findings of the present study (Table I).

The only difference between Type IV andType V is that the MCN does not pierce the coracobrachialis muscle. Venieratos & Anagnostopoulou recorded 3 cases. Loukas & Aqueelah recorded 11 cases and Chitra recorded 3 cases studies, while this study recorded only 2 cases.

Table I. Various classifications of MCN documented in literature.

Author	Specimen	Sample (n)	Total Incidence of communications (n)	TYPE 1 (n)	TYPE 1 (%)	TYPE 2 (n)	TYPE 2 (%)	TYPE 3 (n)	TYPE 3 (%)	TYPE 4 (n)	TYPE 4 (%)	TYPE 5 (n)	TYPE 5 (%)
Le Minor (1989)	Cadaver	50	13	37	74	3	6	3	6	3	6	0	0
Venieratos & Anagnostopoulou (1998)	Cadaver	158	22	136	86	0	0	0	0	19	12	3	2
Choi *et al.* (2002)	Cadaver	276	73	203	74	-	-	-	-	53	19	-	-
Loukas & Aqueelah (2005)	Cadaver	258	119	139	54	-	-	-	-	66	26	11	4
Chitra (2007)	Cadaver	50	13	37	74	0	0	0	0	10	20	3	6
Krishnamurthy *et al.* (2007)	Cadaver	44	7	37	84	-	-	-	-	-	-	-	-
Bhattarai & Poudel (2009)	Cadavers	32	2	30	94	0	-	0	0	2	6	0	0
Guerri_Guttenberg & Ingolotti (2009)	Cadaver and Fetus	56	32	24	43	2	5	-	-	24	43	-	-
Kervancioglu *et al.* (2011)	Fetus	20	7	13	65	0	0	0	0	5	25	0	0
Leng *et al.* (2016)	Cadaver	160	18	142	89	5	3	-	-	9	6	-	-
Present Study	Fetus	50	8	42	84	1	2	1	2	4	8	2	4

All the muscles in the anterior compartment of arm were supplied by the MCN with or without communications with the MN. Only when the MCN was absent, MN supplied all the muscles in the anterior compartment of arm. Other than that, there were no other nerves involved in the innervation of the muscles in the anterior compartment of arm or lateral cutaneous innervation of the forearm.

CONCLUSION

The study showed five possible courses of the MCN, with 16 % of specimens within this study varying from the standard anatomical course. Knowledge of the variations of the MCN, including the communicating branch between MCN and MN, may assist medical practitioners as it may help the in diagnosis and treatment of peripheral nerve lesions, repair for trauma to the shoulder and in comprehending MCN dysfunction (Bhattarai & Poudel; Ballesteros *et al*., 2015; Hayash *et al*., 2017 and Khake *et al*. 2018). These variations are also imperative for flap dissections, to elude iatrogenic neurological damage during surgical procedures of the arm and surgical neck of the humerus and post-traumatic evaluations of the arm (Bhattarai & Poudel; Ballesteros *et al*.; Hayash *et al*., 2017; Khake *et al*.).This study recommends that further studies should be conducted on a larger sample size.

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RESUMEN: El nervio musculocutáneo es un ram terminal del fascículo lateral del plexo braquial y está formado por las raíces espinales de C5, C6 y C7. Las variaciones anatómicas del nervio musculocutáneo (NMC) no son comunes, los informes literarios han descrito el curso diferente del NMC en el brazo, sin embargo, se han realizado muy pocos estudios fetales sobre las variaciones de este nervio. Por lo tanto, el objetivo del estudio fue describir el curso del NMC en fetos y documentar las variaciones. En este estudio, una muestra de veinticinco fetos fue disecada bilateralmente (n = 50) usando un estereomicroscopio. La anatomía del NMC se describió mediante un sistema de clasificación en base a los hallazgos. La aprobación ética se obtuvo del Comité de Ética en Investigación Biomédica (BE385 / 17). El tipo I (anatomía normal) del NMC se encontró en 42/50 (84 %) de las muestras. Se observaron algunas variaciones, por ejemplo: 1/50 (2 %) caso de Tipo II (ausente), 1/50 (2 %) de Tipo III (comunicación entre NMC y nervio mediano (NM), de NM a NMC), 4/50 (8 %) casos de Tipo IV (comunicación del NMC al NM) y 2/50 (4 %) casos de Tipo V (comunicación del NMC al NM, donde el NMC no perfora el músculo coracobraquial). Este estudio proporciona evidencia de variaciones del NMC en fetos que puede ayudar a los cirujanos a interpretar patrones de inervación anormales en el brazo.

PALABRAS CLAVE: Nervio musculocutáneo; Estudio fetal; Clasificación; Variaciones anatómicas.

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