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Anatomical rationale for use of the latissimus dorsi flap during the cardiomyoplasty operation

Bases anatomiques pour l'utilisation du m. grand dorsal durant l'intervention de cardiomyoplastie

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Summary. The cardiomyoplasty procedure involves the use of a transformed skeletal muscle to augment cardiac pump function or to substitute for the heart after parietal resection. This study of the intramuscular vascularization of latissimus dorsi was carried out in order to establish the relationship between the dominant thoracodorsal blood supply and the distal supply issued from the intercostal and lumbar arteries. This data is mandatory for the safe manipulation of the muscle flap during cardiomyoplasty. Thirty human latissimus dorsi flaps were carefully studied. We confirmed anatomically as well as angiographically previous macroscopic anatomical reports, as well as the constancy of the neurovascular pedicle. Three principal branching patterns were observed for the thoracodorsal artery. The thoracodorsal artery divides into three main tributaries in 20/30 (67%), and into two tributaries in 10/30 (33%) of the flaps observed. When three tributaries were observed, one of them was a small recurrent artery for the proximal third of the latissimus dorsi (14/20, 70%). Thus the distal vascularization is actually dependant on three principals in 6/30 (20%) and two principals in 24/30 (80%). From these two or three principals emerge several subsequent longitudinal branches (5 to 9) that have a straight course until their distal anastomoses with segmental arterial pedicles issued from intercostal and lumbar arteries. The latter ligation can thus occur without ischemic damage to the medial and distal aspect of the flap. This study emphasizes that, due to macroscopic anatomic features and systematic intramuscular vascular distribution, the latissimus dorsi is probably the most suitable muscle for the purpose of cardiomyoplasty.

Résumé. Le concept de cardiomyoplastie s'articule sur l'utilisation d'un muscle squelettique transformé, pour augmenter la fonction de pompe dévolue au myocarde, ou pour se substituer à celui-ci après une résection pariétale. La présente étude anatomique, étudiant la distribution vasculaire intramusculaire du m. grand dorsal, a été réalisée pour apprécier la distribution intramusculaire fine, ainsi que les relations existant entre l'apport thoraco-dorsal proximal prédominant et les deux sources d'apport vasculaire périphérique issues des artères intercostales et lombaires. Cette information est indispensable pour permettre une manipulation rigoureuse du muscle lors de la cardiomyoplastie. Trente muscles grands dorsaux ont été soigneusement étudiés. Nous avons confirmé les données macroscopiques déjà publiées, ainsi que la constance du pédicule thoraco-dorsal. Trois modes principaux de division au niveau du hile ont été reconnus. L'artère thoraco-dorsale se divise en trois branches principales dans 20/30 (67%) des cas, et en deux branches principales dans 10/30 (33%) des cas. Quand trois branches sont observées, l'une d'entre elles est une petite branche récurrente pour la portion proximale du muscle dans 14/20 (70%) des cas. En conséquence, la vascularisation distale est en réalité dépendante de trois branches principales dans 6/30 (20%) des cas, et de deux principales dans 24/30 (80%) des cas. De ces deux ou trois branches principales émergent une série de branches longitudinales, qui ont un trajet relativement rectiligne jusqu'à leur anastomose distale, avec les apports segmentaires périphériques issus des artères intercostales et lombaires. La ligature de celles-ci peut donc être réalisée sans risque majeur d'ischémie pour la portion moyenne et distale du lambeau. Les arguments rapportés dans cette étude démontrent que, par ses propriétés macroscopiques et ses propriétés de vascularisation intramusculaire, le m. grand dorsal est probablement le muscle de choix pour la cardiomyoplastie.

Keywords : Cardiomyoplasty ; Latissimus dorsi ; Vascular anatomy

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Electrostimulated transformed skeletal muscles have recently elicited considerable interest in the field of muscle powered cardiac assistance and cardiomyoplasty [1, 3]. Following progressive chronic stimulation, fatigable striated muscle can be turned into a fatigue-resistant one, capable of sustaining chronic work [9, 12]. Such muscles have been used to increase cardiac performance, to replace resected myocardial wall, and/or to power cardiac assist device [4, 5]. Although several muscles have been tried (sternohyoid, diaphragm, rectus abdominis, pectoralis major), the latissimus dorsi because of its evident anatomical features (localization, neurovascular pedicle, surface area) has been favoured by most investigators, following the pioneering work of Carpentier and Chachquès [3, 4, 5].

Most anatomical studies have emphasized the gross anatomy of the flap, the constancy of the neurovascular pedicle, and the rough distribution of the intramuscular vascularization [2, 6, 11, 13]. Since the cardiomyoplasty procedure involves more than a mere transposing of a muscle for closing defects or for anatomical reconstruction, an accurate description of intramuscular distributions was needed. An efficient cardiomyoplasty procedure requires that the most distal part of the muscle be well perfused, implying some anastomoses between the thoracodorsal blood supply and the peripheral intercostal and lumbar vessels. Furthermore, very sharp knowledge of the intramuscular distribution at the hilum is necessary to permit safe implantation of the electrostimulating device.

The present anatomical and angiographic study was conducted to answer both of these questions.

Material and methods

Thirty dissections were carried out on fresh human cadavers (14M, 16W), with an equal proportion of right and left latissimus dorsi flaps. Cadavers were positioned with the ipsilateral arm abducted to 90° at the shoulder, and the elbow to 90° of flexion. An incision was made in the axilla, following the lateral edge of latissimus dorsi. Our study included the examination of the subscapular artery and vein, circumflex vessels, and the thoracodorsal pedicle including collaterals to the serratus anterior. We also focused on the latissimus dorsi nerve relations with the pedicle and the segmental peripheral supply. En-bloc dissection of the whole muscle mass was accomplished. Sharp dissection of the thoracodorsal vessel at the latissimus dorsi hilum level was performed. Lead oxide solution [10] was perfused under constant pressure (130 mm Hg) to highlight the fine intramuselular vascular distribution. Angiographic films were reviewed by surgeons and radiological experts. The emphasis was placed on the branching of the thoracodorsal artery and the muscle vascular supply distribution. Attention was paid to anastomoses between the proximal supply and the distal and medial segmental supply from intercostal and lumbar arteries (Fig. 1).

Results

The subscapular artery was found to arise 3 to 4 cm distal to the acromio-thoracic artery on the axillary artery. It divides early (2-6 cm) into two main branches : the circumflex scapular artery that goes backward into the medial axillary space, and the thoracodorsal artery. We once noted two circumflex scapular arteries arising from the subscapular artery. The thoracodorsal artery, accompanied by one (29/30) or two veins (1/30), quickly reaches the latissimus dorsi nerve that comes from the inner aspect. The thoracodorsal artery follows the lateral edge of the latissimus dorsi (1-2 cm medially) and spreads on its thoracic surface (at the hilum). The artery gives one to three branches to the serratus anterior and then, divides to feed the muscle itself. The branching of the thoraco-dorsal artery into the latissimus dorsi is very irregular and occurs either within the muscle itself or up to 4 cm before it. We found that, contrarily to previously described cases, division into three main trunks occurred in 20/30 (67%) of our series (Fig. 2 and 3). In 14 cases out of these 20 (60%), one of the three branches was a rather small recurrent artery that obviously went upward to provide the vascularization of the muscles' proximal part (Fig. 3). When this artery did not exist, this vascularization was achieved through small recurrent branches issued from the main division trunk of the thoraco-dorsalis artery. If one excludes these recurrent arteries, vascularization of the muscles' distal part was achieved in 80% of the cases by two main division branches (Fig. 3 and 4), and in 20% (6/30) by three main division branches (Fig. 2).

The most lateral artery was always the most important in size.

In 4 cases, evidence existed of a collateral for the serratus anterior derived from this branch. These two or three major branches then divided into several longitudinal arteries that went straight to and progressively deeper into the distal part of the muscle where they anastomosed with perforating arteries derived from the terminal intercostal (9th, 10th, 11th) and first lumbal (1st, 2nd, 3rd) arteries (Table 1). The angiographic data showed important distal contrast pooling as a result of selective perfusion of the thoracodorsalis artery.

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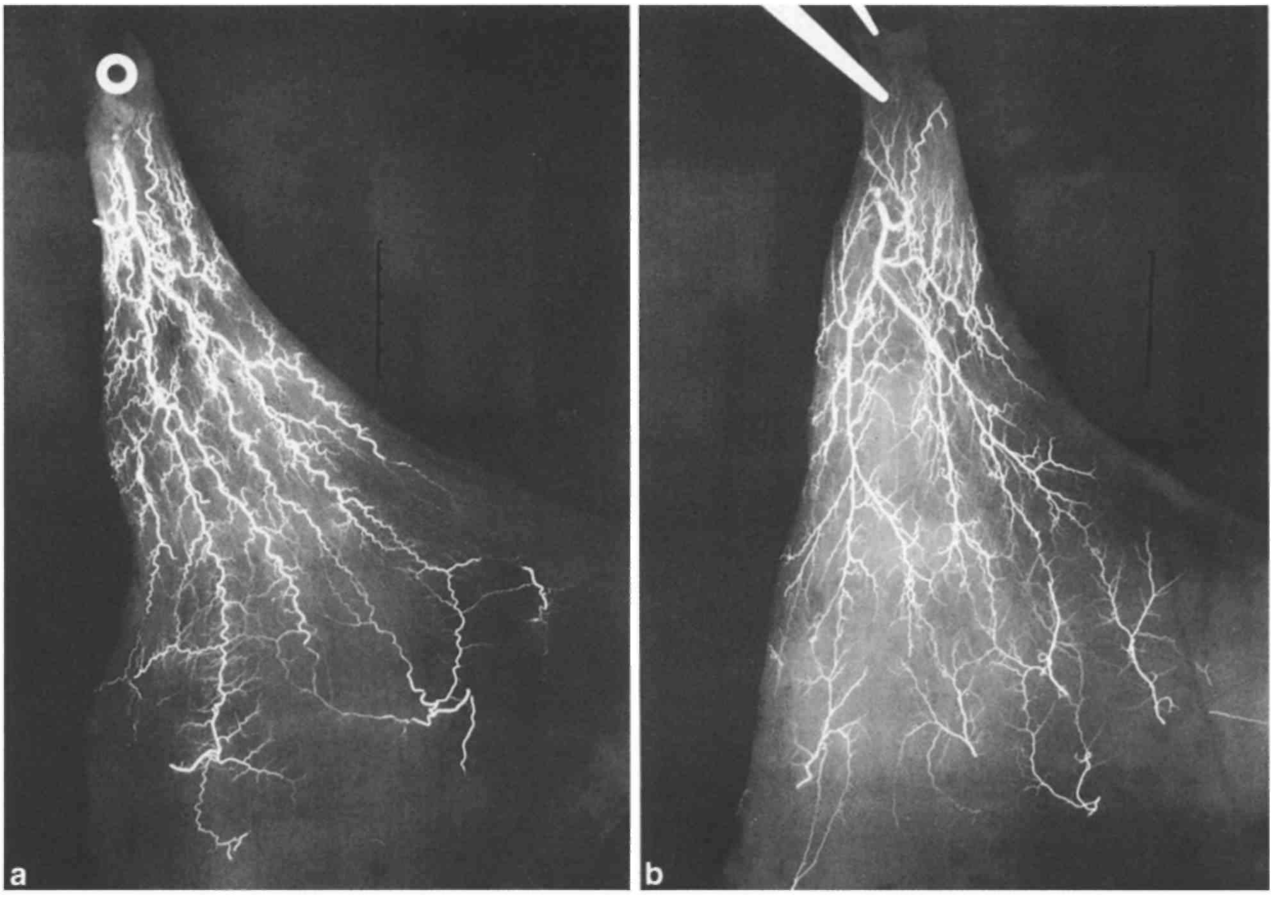
Major branch divisions of the thoracodorsal artery were accompanied by at least one branch division of the latissimus dorsi nerve and veins. These neurovascular structures were situated in the fatty cellular space between musculo-fibrous bundles. Their pathway was easily visualized by gentle traction on the pedicle or by careful dissection. As these structures progress distally, they ramify and plunge deeper into the muscle.

Figs, 1a, b

1 *Lead oxide solution was perfused under constant pressure in a right (a) and left (b) latissimus dorsi. Angiograms of latissimus dorsi a and b show division of the thoracodorsal artery into two or three branches (one of these being a recurrent artery) respectively. Evidence of contrast pooling in the distal aspects of the muscles with retrograde filling of peripheral supply issued from intercostal and lumbar arteries*

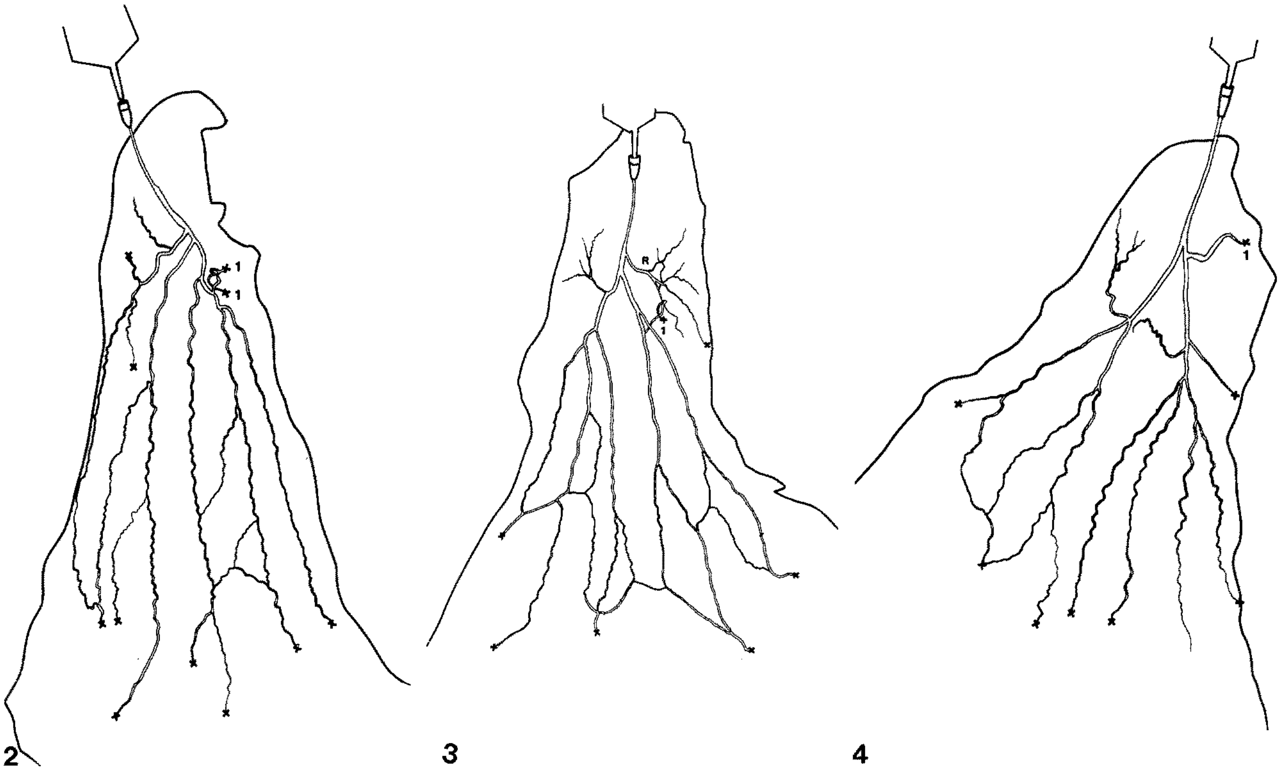
1 *La solution d'oxyde de plomb a été perfusée sous pression constante dans un muscle grand dorsal droit (a) et gauche (b). L'artériographie des muscles grands dorsaux a et b montrent une subdivision de l'artère thoraco-dorsale en deux ou trois branches (l'une d'entre elles est une artère récurrente). Il existe une accumulation de produit de contraste dans la périphérie du muscle, avec un remplissage rétrograde des collatérales périphériques issues des artères intercostales et lombaires*



Figs. 2-4

2 *Division of thoracodorsal artery into three main branches. * = contrast leak, 1 = branch for serratus anterior.* ***3*** *Division of thoracodorsal artery into two main branches. One of them (R) is a recurrent artery, * = constrast leak.* ***4*** *Division of thoracodorsal artery into three main branches. 1 = branch for serratus anterior, * = contrast leak*

2 *Division de l'artère thoraco-dorsale en trois branches principales. * = fuite de contraste, 1 = branche destinée au m. dentelé antérieur.* ***3*** *Division de l'artère thoracodorsale en deux branches principales. l'une d'entre elles (R) est une branche récurrente. R = artère récurrente, * = fuite de constraste.* ***4*** *Division de l'artère thoraco-dorsale en trois branches principales. 1 = branche destinée au m. dentelé antérieur, * = fuite de contraste*



Comments

The latissimus dorsi muscle is a huge triangular flap endowed with two vascular blood supplies, one from the thoracodorsal artery, and the other from the intercostal and lumbar arteries. We confirmed the constancy of the macroscopic neurovascular pedicle thus permitting (due to its length : mean 12 cm) easy transposition and mobilization. Our data is in agreement with Bartlett et al [2], Tobbin et al [13], Salmon et al [11], and El-Maassarany et al [6] previously published results, as far as gross anatomy is concerned. However our angiological study showed that previously reported data concerning intravascular muscular distribution was not accurate enough. We have shown that intramuscular vascularization is achieved by 5 to 9 longitudinal arteries that arise from 2 or 3 main branch divisions of the thoracodorsal artery. This branching occurs within the muscle itself at level of the hilum or as far as 4 cm before it. Division into three main branches occurred in 67% of our samples. In 70% of these cases, the third branch was a recurrent artery that vascularized the proximal part of the muscle. Distal revascularization thus arose from two main branches in 80%, and three main branches in 20% of the muscles studied. In each case, the lateral branch was the most important. Such branching has never been previously reported. Division into three branches without particular specification of its topography is reported to occur in 2% [12], 6% [8], and 0% [7] of the most significant available series. Currently, three main hilum branching patterns can be emphasized : firstly classically described division into two main branches (33%), secondly division into three vessels, one being a recurrent artery (47%), and thirdly branching into three main branches (20%). We focused particularly on the topographic anatomy of the latissimus dorsi hilum, because several steps in the cardiomyoplasty procedure (like implantation of stimulating electrodes sewed in the muscle thickness, following the technique described by Grandjean and Chachquès [7]) can injure proximal vascularization. Providing that the different division patterns are taken into account, we have experienced that surgical implantation of the electrode can be a safe procedure.

Following branching at the hilum, the two or three main branch divisions of the thoracodorsal artery give several longitudinal tributaries that have a straight course up to the distal part of the muscle. They ran close to each other within the muscle and progressively plunge deeper into the muscle thickness. Our angiological data emphasize the distal anastomosis between these branches and the peripheral blood supply issued from the intercostal and lumbar arteries. We illustrated an important distal perfusion through a single thoracodorsal artery injection. These anastomoses are of major importance since good distal perfusion of the muscle flap is prerequisite for further good contractile activity.

Table 1. *Results of 30 dissections*
Résultats des 30 dissections

LD flap number	N° of major bifurcation trunks of T.D. artery	Preponderance the lateral main trunk	LB	DA
1	2	+	5	5
2	2	+	8	3
3	3 (1=R)*	+	5	2
4	2	+	5	4
5	3	+	9	5
6	3 (1=R)*	+	6	4
7	2	+	6	3
8	3	+	6	5
9	2	+	7	6
10	3	+	5	3
11	3	+	5	5
12	3 (1=R)*	+	6	4
13	3 (1=R)*	+	6	5
14	3	+	6	5
15	3 (1=R)*	+	6	5
16	3 (1=R)*	+	5	5
17	2	+	5	6
18	3 (1=R)*	+	5	4
19	3 (1=R)*	+	6	5
20	2	+	5	6
21	3 (1=R)*	+	6	5
22	2	+	7	6
23	2	+	5	4
24	3 (1=R)*	+	6	7
25	3 (1=R)*	+	7	5
26	3 (1=R)*	+	8	7
27	3 (1=R)*	+	5	5
28	2	+	5	5
29	3	+	6	5
30	3 (1=R)*	+	6	5

LB : Longitudinal intramuscular branches; *DA* : number of distal anastomoses with irrigation issued from lumbar and intercostal arteries; *(1=R)* : one of the three main trunks is a recurrent artery

LB : branche ktrarnuseulaire longitudinale; *DA* : nombre d'anastomoses distales avec des branches collatérales des aa. lombaires et intercostales; *(1=R)* : une des trois branches principales est récurrente

Conclusion

Because of its shape, surface and location, the latissimus dorsi fulfills all the necessary requirements needed for being the muscle of first choice for the cardiomyoplasty procedure. It provides surgeons with a muscle of large surface area allowing good wrapping of the heart, and has a constant pedicle of good quality allowing easy transposition in the thorax. The branching of the thoracodorsal artery follows three main patterns and the rich intramuscular vascular network exhibits anastomoses between its proximal and distal supply allowing the suppression of the former without major ischemia. Adequate knowledge of intramuscular vascular distribution preserves the muscle flap from neurovascular damage during the surgical procedure.

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