INTERCOSTAL ARTERY AS AN ALTERNATIVE CONDUIT FOR COMPLETE ARTERIAL MYOCARDIAL REVASCULARIZATION

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To assess potential suitability of the intercostal artery (ICA) as a conduit in myocardial revascularization a morphometric study of intercostal arteries was conducted in 12 adult cadavers. The 4th, 5th, 6th, 7th and 8th intercostal arteries were harvested bilaterally. ICAs were dissected to elucidate the clinical anatomy of these purported anatomosurgical segments together with the both internal mammarian arteries (IMAs). Each ICA was dissected free from the inferior aspect of the rib and removed with a 1-cm-wide pedicle of intercostal muscle. The length of the ICAs varied from 18 to 34 cm (mean, 23.8±4.75). The mean luminal diameter of the ICAs varied from 1.31±0.5 mm at the origin to 0.93±0.4 mm at the distal segment. Mean luminal diameter of the IMAs was 1.34±0.2 mm at the midsegment.

There was no significant difference in luminal diameter among the measured ICAs. Mean diameter of ICAs was 82% smaller than mean diameter of IMAs.

ICA free graft is not difficult to harvest. We concluded that ICAs would potentially be suitable for myocardial revascularization anatomically. Evaluation of the results of experimental studies will determine the true efficacy of the ICA as a reliable conduit for CABG.

Key words: Intercostal artery, arterial conduit, complete arterial revascularization, coronary artery bypass grafting

Complete arterial revascularization has become a favored form of surgical treatment for multivessel coronary artery disease because of the excellent long-term patency of the internal mammarian artery (IMA) (1, 2). The primary consideration that has led to the use of the IMA as the conduit is its relative freedom from atherosclerosis within following 10 years. Because of this consideration, a policy of progressively using more arterial grafts was adopted to achieve complete arterial revascularization (2). As the frequency of primary or secondary coronary revascularization procedures has increased in patients with unsuitable or absent IMAs or saphenous veins, alternative conduits have been sought (3). Strategies to increase the use of arterial conduits are the use of both IMAs, the use of sequential IMA and the use of other alternative arterial conduits, including the radial artery, gastroepiploic artery and inferior epigastric artery (4-7).

The aim of this study is to evaluate the suitability of the intercostal arteries (ICAs) as easily accessible sources of arterial conduits.

MATERIAL METHODS

The measurements were performed in 12 adult male cadavers between 39 and 64 years of age (mean age, 58±3.5 years) who had expired of noncardiac diseases. Cadavers were fixed in 4% buffered formaldehyde solution.

The ICAs were obtained from the thoracic cavity after removing the heart and lungs. The 4th, 5th, 6th, 7th and 8th intercostal arteries were harvested bilaterally. ICAs were dissected to elucidate the clinical anatomy of these purported anatomosurgical segments together with the IMA. Each intercostal artery was dissected free from the inferior aspect of the rib and removed with a 1-cm-wide pedicle of intercostal muscle.

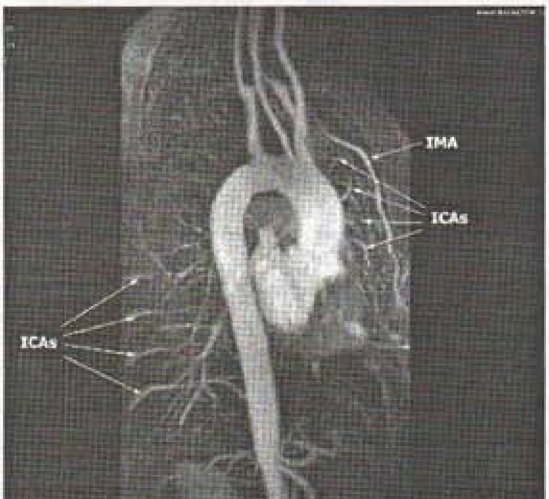
We measured mean luminal diameter in the proximal and distal segments of the 4th, 5th, 6th, 7th and 8th ICAs, and mean luminal diameter in the midsegment of the both IMAs. Also we measured the total length of the ICAs at the origin from thoracic aorta to the connection to the IMA (Figure 1).

RESULTS

There was no significant difference in luminal diameter. Rigor mortis and fixation state have caused a reduction in the luminal diameter of the ICAs.

Mean luminal diameter of the ICAs varied from 1.31±0.5 mm at the origin to 0.93±0.4 mm at the distal segment. Mean luminal diameter of the IMAs was 1.34±0.2 mm at the midsegment. There was no significant difference in luminal diameter among the measured ICAs. Mean diameter of ICAs was 82% smaller than mean diameter of the IMAs.

The right ICAs were longer than the left ICAs due to left sided position of the thoracic aorta. The length of the ICAs varied from 21 to 34 cm (mean, 24.7±5.4) in the right side and 18 to 32 cm (mean, 22.9±3.8) in the left side.



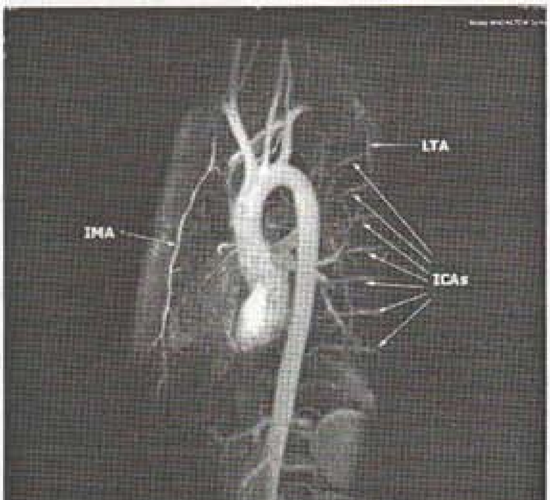


Figure 1. MR angiographic views of the IMA and ICAs. LITA: lateral thoracic artery.

Mean measured values are summarized in Table 1.

DISCUSSION

The systemic arteries serve as a pressure reservoir by means of the elastic properties of their walls. However, arterial grafts are not uniform either in anatomy or function (8, 9). On the basis of embryological, anatomic and physiologic factors, a classification has been proposed for arterial grafts:

Type I Somatic arteries
Type II Splanchnic arteries
Type III Extremity arteries

Embryologically, type I arterial grafts (somatic arteries) are intersegmental branches of the body wall. These vessels persist bilaterally as the internal thoracic artery and the superior and inferior epigastric artery.

Somatic arteries are less reactive than type II and type III. They are mainly conduit arteries. The ITA is a typical example of type I arteries.

Type II arterial grafts (splanchnic arteries) are from the segmental branches of the primitive dorsal aorta supplying the digestive tube. The dorsal splanchnic anastomosis persists in the gastroepiploic artery.

The splanchnic arteries are prone to spasms because of higher contractility of the splanchnic arteries. This characteristic of splanchnic arteries is physiologic, meaning that blood flow through the splanchnic arteries is subject to changes under various circumstances in accordance with the function of the alimentary tract. The flow increases after meals and decreases in critical situations.

Type III arterial grafts (extremity arteries) are located in limbs. The arteries of the upper limb, such as the radial artery, has also developed from intersegmental arteries as type I arteries, although the arteries of the lower limb arise from the dorsal root of the umbilical artery.

Extremity arteries, represented by the RA, have a higher tendency to be subject to spasms compared to the somatic arteries.

The internal elastic lamina and elastic lamellae in the media may have a key role in the prevention of intimal thickening because they form barriers to the invasion of smooth muscle cells from the media into the intima. The mainly elastic character of the media of the IMA is the main reason for the relative freedom from intimal thickening and for the excellent long-term patency (10). Over the long term, there is a striking difference in the late development of atherosclerosis between the time IMA and venous bypass conduits. Comparison of the IMA and vein graft patency reveals a highly significant difference in every time interval. Accelerated vein graft closure because of progressive intimal hyperplasia and atherosclerosis begins in the 5th year and approximates 5% per year, with a 10-year patency rate varying between 41% and 56%. In contrast, 10-year IMA patency rate has been reported to be greater than 80% (2, 11, 12). To overcome the problems of late vein graft atherosclerosis, occlusion and coronary reoperations, a strategy of total arterial coronary revascularization was adopted.

On account of the larger thickness of its muscular layer compared to the other arteries of similar size, the RA is more prone to develop spasm in response to mechanical stimuli. Vasospasm of the implanted RA graft was documented either clinically or angiographically in approximately 5% (4). It has also been thought that there might be a higher morbidity from possible local ischemic complications (sternum or hand) compared to bilateral IMA and RA harvesting.

It is intriguing that the ICA, a vessel comparable to the coronary artery in cross-sectional diameter like the IMA and acclimated to the same arterial hemodynamics,

Table 1. Mean measured values of the ICA and the IMA.

ICA Proximal	Mean	1.31 ± 0.5
	Range	1.11 - 2.0
ICA Distal	Mean	0.93 ± 0.4
	Range	0.7 - 1.6
IMA Middle	Mean	1.34 ± 0.2
	Range	1.2 - 1.5

intrathoracic respiratory pressure changes, and biochemical environment, has such a low incidence of atherosclerosis.

There are no reports on the use of the intercostal arteries as a coronary artery bypass conduit. Cadaveric studies are the basis for surgical anatomy and new surgical methods before they are applied in patients (13). In this study, the ICA has been proposed as a new alternative arterial conduit, and its favorable anatomic characteristics were demonstrated.

The size, length and handling characteristics could make the ICAs versatile arterial conduits allowing distal anastomosis. The 4th to 8th ICAs on the chest wall could reach the heart. The probable diameter of the ICA would be similar to that of a "small" IMA or the right gastroepiploic artery.

The critical issue that remains is whether this conduit is of adequate diameter to completely or partially sustain the coronary circulation. The measured flow of transected intercostal artery at the midaxillary level was 80 to 100 mL/min. This flow rate may be sufficient enough to accept the intercostal artery an a conduit in myocardial revascularization (9). The major concern about the clinical use of the ICA may be its inadequate luminal diameter. The luminal diameter of the proximal ICA better matches that of the coronary artery compared to the luminal diameter of the distal segment.

A potential disadvantage of the use of the intercostal arteries in coronary bypass grafting may be the difficulty in harvesting these arteries because of interference with the lungs and the curvature of the chest wall. The harvesting may further be facilitated by rotation of the operating table towards the surgeon. Also the ICA harvesting could also be adapted to minimally invasive techniques.

Another disadvantage of the use of the intercostal arteries is that these arteries can be used only as free grafts. To perform the proximal anastomosis to the ascending aorta may be technically demanding. The same problem is frequently encountered in radial artery and inferior epigastric artery grafts. Reported patency rates of the free, pedicled IMA grafts approximating that of in situ IMA grafts supports the potential feasibility of use of the ICA as a free graft in myocardial revascularization. This problem may be circumvented by use of an ICA graft in an end-to-side fashion to IMA graft or the other aortocoronary bypass grafts. The ICAs can be used in combination with one or both IMAs as a Y or T graft like radial artery or inferior epigastric artery in composite grafts (5,14). It was reported that the LIMA alone was capable of providing the required inflow for the graft circulation (5,14,15).

CONCLUSION

Advantageous properties of the ICAs with regard to their potential suitability as conduits in myocardial revascularization are they are somatic numeruous easily harvested, and less complicant.

We concluded that the ICAs would potentially be suitable for myocardial revascularization anatomically. Evaluation of the results of the experimental studies can determine the true efficacy of the ICA as a reliable conduit for CABG.

REFERENCES

1. Van Som JAM, Smedts F, Vincent JG, Van Lier HJ, Kubat K. Comparative anatomic studies of various arterial conduits for myocardial revascularization. J Thorac Cardiovasc Surg 1990;99:703-7.
2. Lytle BW, Loop FD, Cosgrove DM et al. Long-term (5-12 years) serial studies of internal mammary artery and saphenous vein coronary bypass grafts. J Thorac Cardiovasc Surg 1985;89:248-58.
3. Calafiore AM, Di Giammarco G, Luciani NN et al. Composite arterial conduits for wider arterial myocardial revascularization. Ann Thorac Surg 1994;58:185-90.

4. Weinschelbaum E, Gabe E, Macchia A, Smmimo R, Suarez LD. Total myocardial revascularization with arterial conduits. Radial artery combined with internal mammary arteries. J Thorac Cardiovasc Surg 1997;114:911-6.
5. Calafiore AM, Di Giammarco G, Teodori G et al. Radial artery and inferior epigastric artery in composite grafts: improved midterm angiographic results. Ann Thorac Surg 1995;60:517-36.
6. Mills NL, Everson CT. Technique for use of the inferior epigastric artery as a coronary bypass graft. Ann Thorac Surg 1991;51:208-14.
7. Akıncı E, Güler M, Bozbuğa N, Kutay V, Dağlar B, Gürbüz A, Işık Ö, Yakut C. Complete arterial revascularization in tripple-vessel disease. Cor Europeum 1999;8:19-23.
8. He GW, Yang CQ. Comparison among arterial grafts and coronary artery - an attempt at functional classification. J Thorac Cardiovasc Surg 1995;109:707-15.
9. Moore KL, Dalley AF. Clinically oriented anatomy. Fourth edition, Lippincott Williams&Wilkins, 1999, pp 88-91.
10. Calafiore AM. Total arterial myocardial revascularization. Thorac Cardiovasc Surgeon 1997;45:105-8.
11. Tatoulis J, Buxton BF, Fuller JA, Royse AG. Total arterial coronary revascularization: technique and results in 3,220 patients. Ann Thorac Surg 1999;68:2093-9.
12. Paolini G, Mariani MA, Benussi S, et al. Total arterial myocardial revascularization. Eur J Cardiothorac Surg 1993;7:91-5.
13. Anderson RH, Wilcox BR. Understanding cardiac anatomy: the prerequisite for optimal cardiac surgery. Ann Thorac Surg 1995;59:1366-75.
14. Barner HB, Johnson SH. The radial artery as a T-graft for coronary revascularization. Operative Techniques Cardiac Thorac Surg 1996;1:117-36.
15. Tector AJ, Amundsen S, Schmahl TM, Kress DC, Peter M. Total revascularization with T grafts. Ann Thorac Surg 1994;57:33-9.