VASCULAR SURGERY

The intramyocardial left anterior descending artery: Prevalence and surgical considerations in coronary artery bypass grafting

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Background. Major coronary arteries usually have a subepicardial course and only dip into the myocardium near or at their termination. However, occasionally a segment of the epicardial artery may have an intramural course, and it is often referred to as a myocardial bridge. The left anterior descending (LAD) artery is the most commonly bridged vessel. Its prevalence has been evaluated at both autopsy and angiography. However, in the literature reviewed it is apparent that there are no reports of the prevalence of the intramyocardial LAD (IMLAD) artery in coronary artery bypass graft (CABG) series.
Objectives. To document the prevalence of the IMLAD artery in a series of CABGs and to describe the surgical techniques used in these cases.
Methods. A retrospective analysis of 1 349 surgical reports of consecutive CABGs performed over a period of 23 years was conducted.
Results. An IMLAD artery was present in 293 patients (21.7%). The prevalence was 20.2% (51/253) in females and 22.1% (242/1 096) in males. The IMLAD arteries extended into the interventricular septum in 3.8% (11/293) of the patients.
Conclusion. An intramyocardial course of the LAD artery is relatively common in patients undergoing CABG and poses a challenge in bypass grafting. Techniques are described to address this anatomical variation when it is encountered at surgery.

Major coronary arteries have a subepicardial course through subepicardial fat and only dip into the myocardium at or near their termination.[1-2] However, sometimes a variable segment of the epicardial artery can have a long intramural course or lie under a short band of cardiac muscle.[3-6] This anatomical arrangement has been variously described as an intramural coronary artery,[7] a submerged coronary artery,[8] a mural coronary artery,[3] a tunnelled artery[9] and, more commonly in anatomical descriptions, a coronary artery with a 'myocardial bridge' (MB).[8]

MBs were first recognised by Rayman in 1737, then by Black in 1805 (both cited by Ferreira *et al.*[10]) and were first described angiographically by Portman and Iwig in 1960 (cited by Loukas *et al.*[11]). The MB is considered to be a congenital anomaly by some authors, while others refer to it as an anatomical variant of a coronary artery.[12-16] The first in-depth autopsy analysis of MBs was done by Geiringer.[3] Clinically, the diagnosis is made by systolic 'milking' of the involved epicardial artery during coronary angiography,[4] due to transient compression of the vessel during systole. However, the present report excluded the short-bridged left anterior descending (LAD) artery where no occlusive lesion was demonstrated angiographically, and patients with symptoms resulting from systolic constriction of the vessel.

Myocardial infarction (MI) of the anterior cardiac wall is usually the consequence of disease in the LAD artery.[17] The LAD artery is most commonly situated intramuscularly, although other vessels may be involved.[10,11,18-20] Clinically, the LAD artery is the most important affected vessel,[10] and in view of the routine use of the left internal mammary artery (LIMA) to graft it, it presents specific challenges to the operating surgeon.

In their autopsy study, Ferreira *et al.*[10] distinguished two types of MBs, viz. superficial and deep. The superficial variation was situated in the interventricular groove and was crossed perpendicularly by muscle fibres. The deep variation had larger muscle bundles than the superficial one and was situated deep within the interventricular septum. Geiringer[3] and Polacek[21] reported fewer atheromatous changes in the intramuscular arterial segment than in the subepicardial arterial segment. Ishii *et al.*[18] also observed that the intramuscular location influences the atherosclerotic disease process in the coronary artery. The MB is therefore regarded by some researchers as an uncommon cause of cardiac disease and considered as benign.[22,23] Conversely, there are reports suggesting that the myocardial bridging increases coronary artery spasm.[24] Furthermore, MBs may be a contributory factor in the development of MI,[7] cardiogenic shock after acute inferior MI,[25] unstable angina,[12] life-threatening cardiac arrhythmias[26] and sudden cardiac death.[14]

The intramyocardial LAD (IMLAD) artery poses difficulty in the localisation of the coronary artery at CABG for revascularisation,[27] and may complicate the procedure.[28] A review of the literature revealed no reports of the prevalence of IMLAD in a surgical series, which was the impetus for this study.

Objectives

The study aimed to record the prevalence and location of IMLAD arteries identified during CABG and to discuss the surgical techniques adopted to address this anatomical variation.

Methods

A retrospective analysis of 1 349 surgical reports of consecutive CABGs in a single surgical series performed over a period of 23 years was conducted. All the operations had been done by a single surgeon. Of the patients 1 096 (81.3%) were male and 253 (18.7%) female, and the age range was 23 - 82 years. The racial distribution was 17 black African (1.3%), 414 white (30.7%) and 918 Indian (68.7%). Clinical reports were accessed from databanks in the private sector in the Durban metropolitan region of KwaZulu-Natal, South Africa. Surgical notes were analysed for details of the prevalence and location (based on the classification of Ferreira et al.[10]) of MBs of the LAD artery and the surgical techniques used. All the cases had been reported by the single surgeon who had done the CABGs. The IMLAD artery was identified at surgery by not being visualised on the surface of the heart in almost its entire course. Short-segment bridged vessels with systolic constriction on angiograms were excluded from the study. Only cases in which more than 50% of the proximal length of the LAD was found to be intramuscular were included.

Results

Prevalence

An IMLAD artery was present in 293 patients (21.7%), with an age range of 23 - 78 years. The prevalence according to gender and race was as follows: 21.6% (51/253) in females and 22.9% (242/1 096) in males; and 29.4% (5/17) in black Africans, 24.1% (221/918) in Indians and 16.2% (67/414) in whites.

Location

The IMLAD arteries did not extend deep into the interventricular septum in 96.2% (282/293) of the cases reviewed (on the basis of the criteria described above), and were classified as superficial. The remaining 3.8% (11/293) were found to be deep in the interventricular septum. Of the patients in the latter group, two presented with poor ventricular function (ejection fraction ≤20%).

Surgical solutions employed

The IMLAD artery was located and grafted within the myocardium in 145 of the 293 cases. In the remaining 148, it was grafted distally where it was superficial and visible

Discussion

Myocardial bridging is generally an incidental finding during coronary angiographic studies, with a prevalence ranging from 0.5% to 36%,[4,5,12,24,27] although the prevalence can be as high as 90%

in autopsy series.[2,6,11] We recorded a prevalence of 21.7%, which is lower than the weighted mean of 50.7% for the prevalence of MBs at autopsy but higher than the weighted mean of 14.3% observed in the angiographic series (Table 1). The higher weighted mean prevalence of MB (50.7%) reported in the autopsy series is not surprising, since many patients with MBs are asymptomatic and therefore do not present for coronary angiography. Furthermore, superficial MBs were encountered more frequently than deep MBs, with prevalences of 96.2% and 3.8% recorded for superficial and deep MBs, respectively. This is comparable to the figures reported by Ferreira et al.[10] of 75% and 25% for superficial and deep MBs, respectively.

Hauser[29] suggested that congenital anomalies of the heart may be a factor predisposing to the early development of coronary artery disease (CAD), and as noted earlier, MBs may also be regarded as a congenital anomaly. In one patient with an MB, aged 23 years, the right coronary artery originated from the left coronary sinus. The combination of an MB and the congenital anomaly may in our view have been a factor predisposing to the early development of CAD in this patient.

When the LAD artery is buried in the myocardium for most of its course, locating the vessel can be very challenging and can translate into extended bypass time and a prolonged ischaemic interval during surgery.[30] In our series various surgical techniques were used to address this anatomical entity. The surgical strategy evolved over the period of this retrospective review. These techniques fall into two broad categories and are discussed as practised chronologically.

Locating the IMLAD artery and grafting it within the myocardium

In the early part of this series, the LAD artery was targeted by direct dissection into the overlying fat and myocardium. The incision was guided by the expected course of the vessel using three criteria:

- Using reference points distally (the visible terminal portion of the LAD artery) and proximally (the lateral edge of the main pulmonary artery), and appreciating that the bridged artery takes a straight course and lacks tortuosity.[31]
- Using the 'groove sign'. This refers to an epicardial groove that is said to lie directly over the LAD artery. It is anecdotally referred to as the 'address' for the vessel. This sign was found to be unreliable, as there are frequently several grooves in this epicardial territory. The validity of this sign forms part of an ongoing study.
- Using the 'vein sign'. Some surgeons believe that the IMLAD artery is directly below the anterior cardiac vein. This was used in eight cases, and was found to be useful in locating the artery. The validity of the relationship observed between vein and artery also forms part of an ongoing investigation.

The above technique using any of the reference points described has distinct disadvantages. Firstly, the right ventricular cavity may inadvertently be entered. In our series this occurred in three cases, all of which were safely repaired. Secondly, the myocardial incision

Table 1. Incidence of myocardial bridging at autopsy, angiography and surgery

Author(s)	Population group	Sample size, N	Bridges, n	Prevalence, %	Remark
Autopsy					
Geiringer[3]	Scottish	100	23	23.0	LAD
Edwards et al.[2]	American	276	15	5.4	All coronaries
Polacek[21]	Czech	70	60	85.7	All coronaries
Lee and Wu[32]	Taiwanese	108	63	58.3	All coronaries
Ishii et al.[18]	Japanese	642	270	42.0	All coronaries
Ferreira et al.[10]	Brazilian	90	50	55.6	All coronaries
Kosiński and Gryzbiak[19]	Polish	100	41	41.0	All coronaries
Bandyopadhyay et al.[6]	Indian	42	38	90.4	All coronaries
Weighted mean				50.7	
Angiography					
Noble et al.[4]	Canadian	5250	27	0.5	All patients
Irvin[27]	American	359	35	9.7	All patients*
Wymore et al.[33]	American	64	21	32.8	Heart transplant patients
Soran et al.[8]	Turkish	2 547	26	1.0	All patients
Teragawa et al.[24]	Japanese	114	41	36.0	Patients with chest pain
Mookadam et al.[12]	American	14 416	226	1.6	All patients
Weighted mean				14.3	
Surgery					
Vanker et al. (present study)	South African	1 349	293	21.7	CABG patients

LAD = left anterior descending artery; CABG = coronary artery bypass graft.
*Excluding patients with severe coronary artery disease.

is often accompanied by troublesome venous bleeding not always apparent in the arrested heart and difficult to control later. In the early part of the series, the epicardial edges around the LIMA pedicle were approximated to control venous bleeding. It was suspected that this method of controlling venous bleeding caused three cases of narrowing of the LIMA graft above the point of insertion found at re-study of these patients, who had recurrent symptoms.

Later in the series, the position of the intramuscular vessel was located with pinpoint accuracy. An incision was made over the terminal part of the LAD artery, close to the apex. A tiny 0.5 mm puncture of the vessel was made, and a malleable vascular probe inserted and directed proximally. The fat and myocardium overlying the vessel were incised directly onto the tip of the probe. The distal opening in the vessel was closed with a suture through the adventitia only. This took the guesswork out of locating the artery, but did pose the problem of venous oozing from the incised muscle, and involve the need to make an additional arterial incision.

Grafting the IMLAD artery distally, where it is superficial and visible

The problem here is that of adequate length of the LIMA pedicle. This is especially the case when the left lung is voluminous and crosses the midline. The problem of inadequate length was resolved in two ways:

- Earlier in the series, the LIMA pedicle was augmented by attaching a short length (usually 2 - 3 cm) of vein end-to-end to the artery, to create a variant of a composite arteriovenous graft. This experience is being separately documented, and longer-term follow-up data are being collected. A remarkable feature of cases that have been re-studied is the inability to differentiate the vein from the artery in terms of calibre.

- The currently preferred technique involves re-routing of the LIMA pedicle. In this method a shortened route for the LIMA pedicle is created, so that it can easily reach the distal point of insertion without tension. The parietal pericardium and parietal pleura, and the intervening thymus gland and mediastinal fat, are incised to a point 1 cm from the left phrenic nerve. The LIMA pedicle lies in this groove, medial to the lung, and is not stretched by the inflated lung, irrespective of its volume. This technique has made it unnecessary to dissect out the LAD from its deep position within the myocardium. Many re-studies of distal LIMA attachments to the LAD artery have been performed and the grafts were shown to be functioning well by providing prograde and retrograde blood flow.

During the 30-day follow-up period, which was complete in this series, the prevalences of postoperative bleeding and mortality were similar for the two surgical solutions employed.

Conclusion

An intramyocardial course of the LAD artery is not infrequent, as it was found in at least one in five surgical patients in the CABG series presented. The IMLAD artery may present the surgeon with technical challenges. Various surgical techniques used over the study period are described, and a simpler currently preferred technique is described, which is safer, more reproducible and quicker to execute than earlier methods.

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