Case report
High-frequency ultrasound-guided late surgical revascularisation of chronically occluded left anterior descending coronary artery

Yoshito Inoue *, Ryuichi Takahashi, Koji Tsutsumi, Kenichi Hashizume
Department of Cardiovascular Surgery, Saiseikai Utsunomiya Hospital, Takebayashi 911-1, Utsunomiya, Tochigi, 321-0974, Japan

Abstract
A few successful reports exist of late revascularisation of an ‘occluded’ left anterior descending coronary artery (LAD) with no angiographically visible collateral circulation. Epicardial high-frequency ultrasound and colour Doppler mapping can directly provide accurate anatomical landmarks and also detect very slow coronary flow velocities, with greater sensitivity than coronary angiograms. Late revascularisation of a chronically occluded LAD was performed successfully in two diabetic patients using high-frequency epicardial echo guidance. This had a positive effect on the left ventricular ejection fraction in the hibernating myocardial segments, and there were no subsequent cardiac events as well. These results indicate that the poor prognosis in diabetic patients with very severely reduced left ventricular function and reduced myocardial viability may be improved by late surgical revascularisation of chronic total occlusion (CTO) with no retrograde collateral channel.

Keywords: Coronary artery bypass grafts; Echocardiography; Late revascularisation; Myocardial hibernation; Angiographically negative

1. Introduction
Non-visualisation of the distal end remains a strong contraindication against attempting chronic total occlusion (CTO) using percutaneous coronary intervention (PCI). As a result, surgical intervention is the only way to salvage regional ischaemic myocardium in cases of CTO with Rentrop grade 0 collaterals [1]. Since atherosclerosis is very severe in poorly controlled diabetic patients with uncollateralised CTO, it is difficult to judge graftability and also difficult to decide the best grafted patent coronary portion for anastomosis based on palpation and appearance alone. For patients with total occlusion of the left anterior descending coronary artery (LAD) with no visible collateral channels and no myocardial viability, late revascularisation is assumed to be ineffective. In these cases, alternative treatment strategies such as transmyocardial laser revascularisation have sometimes been recommended [2].

In fact, total revascularisation would be optimal even in emergency surgical treatment for unstable patients with multiple-vessel disease. To choose the patent grafted portion with a less atherosclerotic site from a chronically occluded LAD without collateral channel, the only suitable imaging technique is high-frequency ultrasound [3]. This permits an evaluation of the range and diameter of the residual patent coronary cavity of uncollateralised CTO. We report the successful late revascularisation of invisible CTO of LAD performed on two diabetic patients with severe left ventricular dysfunction using high-frequency epicardial ultrasound guidance.

2. Case report
The first patient was a 63-year-old woman who was admitted for unstable angina. She had diabetes mellitus (HbA1c 8.7), hyperglycaemia, a history of myocardial infarction and a failed PCI to LAD. Coronary angiogram showed CTO of LAD without any retrograde collateral filling and 99% stenosis of the left main coronary artery. Viable myocardium in the distal anteroseptal region was uncertain, according to 99mTc-tetrofosmin perfusion single photon emission computed tomography (SPECT).

The second patient was a 60-year-old woman, with diabetes mellitus (HbA1c 10.9), hyperglycaemia and hypertension, who was admitted for severe acute myocardial infarction (peak serum creatinine kinase 2281 IU ml⁻¹, MB fraction concentration 104.6 IU ml⁻¹). The angiogram revealed triple-vessel coronary artery disease with CTO of LAD without any retrograde visible collateral filling (Fig. 1A) and severe left ventricle (LV) dysfunction (EF 27%).
Since both patients had multiple-vessel coronary artery disease in an unstable condition, and required continuous intravenous administration of heparin and isosorbide dinitrate, surgical intervention was undertaken. No patent cavity was assumed on the basis of appearance or palpation of LAD in either case, because the entire length of the LAD appeared to be severely atherosclerotic and was diffusely covered with fibrous adventitial tissue. The LAD was stabilised with the heart beating and was investigated by high-frequency epicardial ultrasound and non-laminar colour Doppler signal distal to the long CTO of segment 6 of the LAD (Fig. 1C). A coronary incision was made at the most proximal site having the largest diameter with positive colour Doppler signal, based on epicardial mapping; the left internal thoracic artery (LITA) was then anastomosed to this portion. Insertion of a 1-mm coronary dilator revealed distally the presence of a similar patent coronary cavity, which was observed only by high-frequency epicardial ultrasound and was completely occluded angiographically. After anastomosis was completed, graft flow was confirmed to be adequate by transit-time flow measurement. Both patients recovered well and were discharged uneventfully. Postoperative angiogram 6 months later, and CT angiogram 12 months later, demonstrated patent LITA perfusing the spatial extent of the anteroseptal wall (Fig. 2A), which had been totally angiographically negative prior to surgery. The ejection fraction improved from 36% to 51% (Fig. 2B) and post-operative 99mTc-albumin blood pool imaging indicated recovery of the hibernating myocardium in the anteroseptal lesion. The patients were followed up for 24—33 months in the New York Heart Association class I without any cardiac events.

3. Discussion

We find that intra-operative epicardial high-frequency ultrasound and colour-flow mapping can be used by surgeons to determine the extent of occlusion and detect the range of patent cavity in the LAD without retrograde collateral filling. Epicardial high-frequency ultrasound can directly examine the target vessels and also detect coronary flow velocities of 5—12 mm s⁻¹ at the lower limit [4,5], which is more sensitive than a coronary angiogram. Its advantages over angiography are particularly clear in CTO cases without retrograde collateral channel.

Indication of revascularisation depends on the viability of the myocardium; well-developed coronary collaterals on the preoperative angiogram are assumed to be the primary determinant of postoperative left ventricular function recovery after revascularisation [6]. Patients with poorly treated diabetes often present with impaired collateral formation and accelerated atherosclerosis so that very limited viable myocardium would be expected in the CTO region in the absence of collaterals [7]. However, our experience clearly shows the discrepancy between angiographic and ultrasonographic information concerning CTOs, in which the range of the actual occluded segment could not be detected preoperatively. Furthermore, surgical revascularisation of CTO without angiographic collateral flow successfully salvaged the local hibernating myocardium and contributed to the recovery of impaired left ventricular function. This observation suggests that selection of the optimal anastomotic site is crucial, since it ensures sufficient patency in the long term in angiographically negative CTO and also indicates that the coronary network is sometimes preserved like a dried-up canal even in cases of uncollateralised CTO; consequently, the late open artery hypothesis [8] may be more relevant to surgical revascularisation than PCI [9]. In addition, unlike PCI for CTO, surgical intervention carries no risk of distal micro-embolisation of
atherothrombotic plaque during revascularisation, which is likely to impair ventricular functional reserve and cause myocardial damage; as a result, surgical intervention for persistent occlusion after myocardial infarction would be more effective than PCI [10].

In conclusion, high-frequency epicardial ultrasound imaging provides accurate anatomical landmarks of CTO with Rentrop grade 0 collateral during surgical intervention and late revascularisation of angiographically negative CTO has contributed significantly to the recovery of impaired left ventricular function.

References