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# Endoscopic Doppler for Detecting Vessels in Closed Chest Bypass Grafting

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## ABSTRACT

A new method of endoscopic ultrasonography during endoscopic bypass grafting is described. Using a 7.5 MHz ultrasonic catheter (AcuNav, Acuson, Mountain View, CA) that was introduced through a 5mm port and manipulated by robotically enhanced endoscopic instruments, detection of the internal thoracic artery (ITA) and the left anterior descending (LAD) artery was possible through layers of fat and muscle in a canine model.

## INTRODUCTION

The use of computer enhanced telemanipulation systems has enabled a total endoscopic approach for coronary artery bypass (CAB) grafting on the arrested as well as on the beating heart [Reichenspurner 1999a, Reichenspurner 1999b, Damiano 2000, Falk 2000a, Falk 2000b]. With the use of the early endoscopic systems, technical problems that are in part attributable to the lack of tactile feedback are evident. Also, in patients with well-developed overlying musculature, the internal thoracic artery (ITA) is not easily visible from a thoracoscopic approach. These factors not only prolong the ITA harvest, but also increase the potential of graft injury. As regards to the target coronary vessels, an intramyocardial course or excessive epicardial fat in some cases further complicates a less invasive or limited access revascularization procedure. Other issues with visualization using endoscopic techniques include a different view or orientation (lateral access for the endoscope), small fields of view, and high magnification (up to 10x), which limits the use of landmarks and may lead to the misidentification of the target vessel. Finally, a totally endoscopic approach does not allow for adequate assessment of anastomotic patency other than visual inspection, thereby relying on postoperative angiographic imaging for confirmation of patency.

Based on the findings of others using epicardial ultrasonography, [Cartier 1996, Oda 1998, Arruda 1999], we thus evaluated the role of endoscopic ultrasonography to: 1) detect the ITA and its side branches through overlying musculature, and 2) identify and determine the course of the left anterior descending (LAD) through overlying muscle or fat.

## MATERIALS AND METHODS

Evaluation of the 7.5 MHz ultrasonic catheter (AcuNav, Acuson, Mountain View, CA) that was originally designed for percutaneous intracardiac use and not currently approved for human use in an endoscopic setting was performed in a canine model. This probe provided B-mode, color Doppler and continous–wave (CW) Doppler imaging. Through three thoracoscopic ports, the videoscope and the two arms of the da Vinci telemanipulation system (Intuitive Surgical, Mountain View, CA) were placed into the left pleural cavity after left lung deflation. Through a 5mm Port in the fifth intercostal space, the ultrasound catheter was advanced and manipulated with the two graspers controlled from the surgeon's console. Both the videoscopic image and the ultrasound image were displayed at the surgeon's console using an image in image technique. Due to limited availability of the probe, only a single canine experiment was performed.

Since the LAD in dogs is epicardial, the ultrasound probe was placed on top of the intact pericardium and pericardial fat to simulate a subepicardial or intramyocar-

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dial LAD. The animal received humane care in compliance with the "Principles of Laboratory Animal Care", formulated by the National Society of Medical Research, and the "Guide for the Care and Use of Laboratory Animals", prepared by the Institute of Laboratory Animal resources and published by the National Institutes of Health (NIH Publication No. 85-23, revised 1985).

## RESULTS

Based on the ultrasonic image, the ITA was successfully harvested and the LAD identified. Although, the proximal part of the ITA in the canine model is clearly visible, the middle and distal portions are covered by a thick layer of overlying musculature. Using the telemanipulator to guide the ultrasound probe, it was easy to identify and follow the course of the ITA and to identify side-branches and the distal bifurcation. Figure 1 (◎) shows the proximal uncovered portion of the left ITA and the obtained color and Doppler flow signals by direct contact with the vessel. In Figure 2 (◎) the probe is placed on the intercostal muscle (mid-portion of the ITA). The combination of color Doppler and CW Doppler permitted rapid detection of the ITA and its branches in this area to the level of the ITA-bifurcation (Figure 3, ◎). The Doppler probe allowed the detection of the LAD through layers of pericardial fat. Figure 4 (◎) shows the probe placed on the pericardium between the pads of an endoscopic stabilizer that was placed to locally immobilize the heart. The LAD is clearly not visible by direct videoscopic vision, but the ultrasound signal shows the LAD as well as a collateral branch. Using CW Doppler, the typical flow pattern of the LAD provided confirmatory evidence (Figure 5, ◎).

## DISCUSSION

Using epicardial intraoperative ultrasonographic imaging (linear 6.5-MHz wide-band transducer) in patients undergoing conventional bypass surgery, Arruda et al. [Arruda 1999] have been able to visualize the LAD and ITA grafts during cardioplegic administration and reperfusion. Cartier et al. [Cartier 1996] used a 8 MHz scanning probe for epicardial continuous-wave Doppler ultrasonography. They reported a 40% drop in systolic frequency related to grafting of the internal thoracic artery. While mean systolic frequency decreased, the mean diastolic frequency doubled. Similar results have been reported by Oda et al. [Oda 1998] who concluded that ITA grafts seemed to function well when the biphasic diastolic predominant flow could be demonstrated.

Total endoscopic bypass grafting has been performed using the da Vinci telemanipulation system (Intuitive Surgical, Mountain View, CA) [Loulmet 1999, Falk 2000a, Kappert 2000]. However, this technique and limited access coronary revascularization procedures can be complicated by the fact that the ITA graft and the target coronary vessel may not be clearly visible. Additionally, since the target coronary vessel cannot be palpated using an endoscopic approach, calcification or severe plaque at the region of the proposed anastomosis may not be appreciated until the vessel is isolated. Using an endoscopic ultrasound probe, the ITA and its side branches can be easily visualized, thereby facilitating graft harvest. Endoscopic ultrasound may also assist in identifying the target coronary vessel and determining the ideal location for an anastomosis in the absence of tactile feedback. With the help of ultrasound, sites of low calcification can be detected.

Additionally, endoscopic color and CW Doppler permits assessment of the quality of the anastomosis by measuring the direction of flow and the phasicity of the flow pattern. The probe used in this study was intended for intracardiac and not endoscopic use. Future probes with higher or optimal frequencies designed for the topography of the retrosternal region and the surface of the heart, are likely to provide greater image definition, thereby facilitating endoscopic cardiac surgery.

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## REVIEW AND COMMENTARY

***1. Editorial Board Member AR11 writes:***

This is an inevitable progression in the development of closed chest bypass surgery, making use of all types of instrumentation. While the authors apparently can use the Doppler probe to facilitate the procedure, their presentation is muddled. As indicated by the authors, the dog is not a particularly good model as the vessels are epicardial and easy to spot. Perhaps if the experimental demonstration were repeated in another species, e.g., a series of pigs or sheep, the results might be more readily accepted.

***Authors' Response by Volkmar Falk, MD***

It was not the purpose of this communication to present a large body of data, but to demonstrate the possible application of a technique that has been shown useful in conventional surgery in an endoscopic environment. We will continue using a similar device in a human trial soon. This trial will answer the important question if the probe will be sensitive enough to help localize stenoses, calcified areas, and healthy parts of the native coronary circulation.

Both in pigs, as well as in sheep, the coronaries are equally superficial. It is only in humans that the coronary may be covered by fat or run intramyocardial. To prove the concept, the dog model was suitable as it could be shown that endoscopic detection of vessels is possible under layers of muscle and fat.

***2. Editorial Board Member EE455 writes:***

This may be a key technique to enable later routine endoscopic coronary artery bypass grafting (CABG). The authors should provide more practical insights about the technique's interpretation and feasability.

a. Is the signal easily sampled and identified? Are there artifacts?
b. Can the probe be bent, and if not, is it technically feasible in the future? (As far as Figure 1 (◉) shows, the course of the LITA is very tangential to the probes tip and might in some cases be out of its reach, unless the probe is flexible).
c. Did the technique provide information about graft patency? (This being evoked as an option in the Introduction.)

***Authors' Response by Volkmar Falk, MD:***

a. Sampling of the image is readily achieved. The small diameter of the target vessels require a high frequency which naturally limits the depth. Artifacts could potentially come from blood flow inside the ventricle, but the combination of 2D-imaging, color flow Doppler, and CW Doppler allows correct interpretation of the signal.
b. The probe used is built for transvascular intracardiac use and is infact bendable, using the tools of the telemanipulation system. The design of a probe that would be made for endoscopic use would of course have a somewhat different design with a more flat transducer.
c. In this case, the anastomosis was not performed and graft patency was therefore not tested using the probe. Patency of grafts has been tested in other studies using similar technology (see references).

***3. Editorial Board Member PB44 writes:***

What might the cost implications be for this device?

***Authors' Response by Volkmar Falk, MD:***

The Doppler probe used for this study was a disposable probe made for transvascular intracardiac use. The price of these devices (greater than $1,500 US-Dollar) is prohibitive for a routine endoscopic application in a procedure that is already expensive. Reusable probes will therefore be required in the future.

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