

Tissue Microangiography Using a Simplified Barium Sulphate Cadaver Injection Technique

B K Tan,**MBBS, FRCS (Edin)*, R T H Ng,***DMT*, N S Tay,****DCR (R), Dip MS*, B S Tan,*****FAMS, MBBS, FRCR*

Abstract

This study investigated the application of soft tissue X-ray imaging as a method of studying vascular anatomy in injected cadaveric specimens. The arterial system of the anatomical region of interest was perfused with a barium sulphate-gelatin suspension. After curing, the tissues were removed by meticulous dissection and examined using the soft tissue X-ray imaging system. This technique of microangiography was able to demonstrate the entire arterial system of the perfused specimen. This simplified technique shows great potential in the study of vascular anatomy of flaps.

Ann Acad Med Singapore 1999; 28: 152-4

Key words: *Dissection, Radiography, Vascular anatomy, X-ray imaging*

Introduction

The understanding of blood supply is the cornerstone of successful tissue transfer in reconstructive surgery. This understanding has been derived largely from cadaveric dissections, combined with injections to outline the blood supply. The major artery or pedicle perfusing the area of interest is cannulated and injected with mixtures which solidify to preserve the vascular system. Commonly used injectants include coloured latex, methylene blue and radio-opaque substances like lead oxide and barium sulphate. Coloured latex will solidify to a rubbery consistency when in contact with formaldehyde, making it easy to dissect out the vascular tree. Radio-opaque injection techniques depend largely on radiography to define vascular anatomy and are less dependent on gross dissection. Furthermore, radiography is able to detect and demonstrate fine radicals of the arterial system, which is a distinct advantage over non-radio-opaque injection techniques.

Specimens injected with a barium sulphate-gelatin mixture were initially examined using conventional radiography. However conventional radiography was abandoned because of poor resolution where only large size vessels were visualised. This led us to explore soft tissue X-ray imaging techniques for mammography, which were known to be more sensitive and able to

detect slight differences in radiographic contrast. After a series of trial and error attempts with the mammography imaging unit, the optimal setting for exposure was derived, producing excellent results. The entire vascular trees, from artery down to the capillaries, were clearly defined with good resolution, producing images of publication quality.

This simple and inexpensive imaging technique using a readily available mammography unit is ideal for studying vascular anatomy of tissues. The intricate details captured by this technique can demonstrate circulatory patterns within skin and muscle, and therefore improve the understanding of skin and muscle flaps.

Materials and Methods

Preparation of Injectant

Micronised barium sulphate, available as a partially water soluble white powder, is routinely used as contrast material for gastrointestinal imaging. Gelatin can be purchased from the supermarket.

In this technique, 2 g of gelatin was added to a beaker containing 100 ml of water. The mixture was heated gradually to 60°C in a water bath and then left to cool at room temperature once all the gelatin had dissolved. Approximately 50 g of barium sulphate (Fushimi Pharmaceutical Co, Kagawa, Japan) was

* Registrar

Department of Plastic Surgery

** Assistant Manager

Department of Experimental Surgery

*** Assistant Manager

**** Consultant

Department of Diagnostic Radiology

Singapore General Hospital

Address for Reprints: Dr Tan Bien Soo, Department of Diagnostic Radiology, Singapore General Hospital, 1 Hospital Drive, Singapore 169608.

added to 100 ml of the warm gelatin solution to produce a milky suspension. The suspension was thoroughly stirred before injection as the barium had a tendency of settling to the bottom of the container. It was after a series of trial and error experiments that this recipe was derived, to achieve a sufficiently thin suspension which could perfuse the subdermal plexus, and at the same time, be sufficiently radio-opaque to give high quality images.

Preparation of Cadaver

This technique was used to study the blood supply of the lateral arm flap ($n = 6$) and the lower trapezius flap ($n = 2$). During surgical exposure of the major arterial pedicle, all cut vessels were sealed with cautery or ligatures to prevent subsequent leakage of injectant. The artery was cannulated using a 14 or 16 G catheter and the system "flushed through" with normal saline to clear the vascular tree of blood and clots. The catheter was secured to the cut end of the artery with a number of silk ties to prevent leakage.

In all specimens, between 20 and 40 ml of barium-gelatin suspension was sufficient to completely perfuse the vascular system. Leakage of injectant from a superficial nick on the skin at the distal tip of the specimen (e.g. finger tip of an upper limb) indicated that the system had been completely filled by the procedure. The arterial catheter was sealed to prevent back flow and the cadaver stored at 4°C overnight to allow the gelatin to set.

Tissue Harvest

During tissue harvest, the entire portion perfused by the injected vessel was removed and subjected to X-ray examination. Care was taken to ensure that tissue belonging to an adjacent vascular territory was not inadvertently included in the specimen for imaging. This was because radiography, being a two-dimensional study, is unable to differentiate between two separate but adjacent superimposed vascular territories. In the process of tissue retrieval, all cut vessels were sealed to prevent leakage of injectant.

Radiography

Radiography was performed using a dedicated mammography imaging system (Mammomat 2, Siemens, Erlangen, Germany). The specimens were radiographed using exposure factors of 25 kVp and 5.6 mAs at a source-image-distance of 60 cm using standard mammography film-screen systems. Because the facility was primarily designed for breast imaging, the size of the specimens was limited to 24 x 30 cm or less. Any specimen that exceeded these dimensions was imaged in part. Lead radio-opaque markers were found to be useful for identification of key structures.

Discussion

The history of post-mortem injection studies to investigate cutaneous circulation dates back to 1936 when Salmon described a radio-opaque preservative which he injected into fresh cadavers.¹ The mixture consisted of lead oxide (Pb_3O_4) and phenol, which was able to demonstrate vascular anatomy as well as preserve tissue. However Salmon's original mixture was found to be insoluble, resulting in poor penetration of the vascular system. This led to a modification by Rees and Taylor who used a more soluble form of lead oxide (PbO), combining it with gelatin.² With this modified mixture, the authors were able to produce radiographs of high quality both in contrast and detail. However, the authors cautioned that lead oxide was toxic and strict precautions were necessary. A mask and gloves were worn while preparing and injecting the mixture. Surplus mixture and all contaminated equipment, had to be destroyed by incineration. The mixture, they cautioned, was not to be emptied into the sewerage.

In search of a safer and more readily available compound, we tried barium sulphate, which was partially soluble in water, combining this with gelatin. The gelatin solidified with refrigeration, keeping the barium sulphate evenly distributed within the arterial system and preventing spillage into the tissues during dissection. Next, we found that conventional X-rays were unsuitable as only major vascular channels were visualised. We then discovered the works of Nakajima who published high quality radiographs obtained from soft tissue X-rays of lead oxide injected cadaveric specimens.³ The authors accomplished this by using the Softex imaging system (Softex Inc, Tokyo, Japan) to study cutaneous circulation of the back.

Using a dedicated soft tissue X-ray mammography unit that is available in most diagnostic radiology departments, we found that radiographs of comparable quality could be obtained (Figs. 1 & 2). The mammographic imaging process was able to capture the fine ramifications of the arterial system filled with the barium sulphate-gelatin mixture.

Some practical points regarding injection deserve mention. One should avoid excessive pressure during injection as this might cause the smaller radicles of the arterial tree to burst, resulting in extravasation of the contrast mixture into the surrounding soft tissue. Any leakage point during injection should be sealed promptly by cautery or ligatures. Similarly, dissection should not be commenced before the mixture has set as leakage will result in messy staining of the surrounding tissue and obliteration of fine details. One can vary the consistency of the mixture by altering the proportion of the barium sulphate and gelatin. A thinner mixture will penetrate easily into the fine radicles of the arterial tree, whereas a



Fig. 1 Microangiography of the extended lateral arm flap. Observe the fine ramifications of the posterior radial collateral artery (PRCA) supplying the flap. Markers orientate the specimen. (A: anterior)

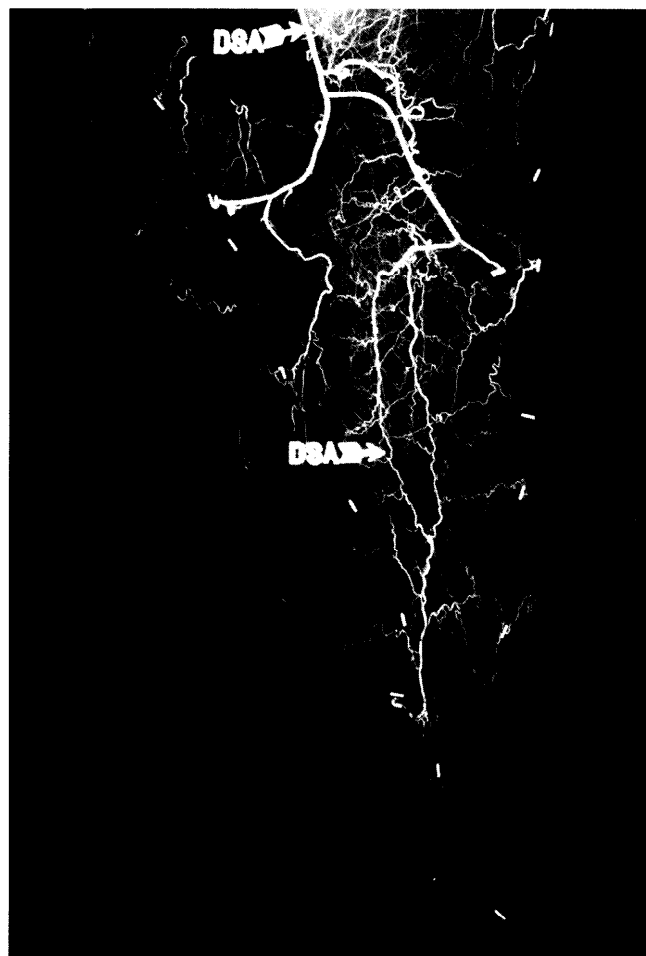


Fig. 2 Microangiography of the lower trapezius muscle. The dorsal scapular artery (DSA) is the main arterial supply to the lower trapezius flap

suspension with a thicker consistency retains better in large vessels.

Summary

A safe, readily available injectable substance is described for the study of arterial circulation in the cadaver. This injectant consists of barium sulphate and gelatin in water forming a radio-opaque suspension. Exceptionally high quality radiographs of injected cadaveric specimens can be obtained using a mammography unit for soft tissue imaging. Using this technique, the vascular anatomy of an injected specimen can be visualised in fine detail with remarkable clarity.

Acknowledgements

The authors would like to thank Dr Tan Kim Ping,

Head, Department of Diagnostic Radiology, Singapore General Hospital, for the use of the radiographic facilities. This project was sponsored by a grant from the Department of Clinical Research, Ministry of Health.

REFERENCES

1. Salmon M. Arteres de la Peau: E'tude anatomique et chirurgicale. Paris: Masson, 1936.
2. Rees M J W, Taylor IT. A simplified lead oxide cadaver injection technique. *Plast Reconstr Surg* 1986; 77:141-5.
3. Nakajima H, Imanishi N, Minabe T, Fujino T, Aiso S. Three-dimensional reconstruction of cutaneous arteries of the back by computer graphic imaging. *Plast Reconstr Surg* 1997; 100:381-9.