Novel Cadaver Injection Method Using Latex and Magnetic Fluid

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Summary: Vascular injection into extracted tissue may be associated with leakage due to excessive local injection pressure. Historically, this complication has been impossible to resolve because the injection pressure has been the only available force with which to send the agent to the peripheral vasculature. We have developed a new vascular injection method that utilizes a material affected by magnetic force and is therefore not solely dependent upon the injection pressure.

We mixed the same weights of latex and magnetic fluid and injected the solution into the arterial stump of an extracted tissue specimen. Next, we used a permanent magnet to attract the agent into the peripheral vasculature. We repeated the injection and magnetic application until no further fluid could be injected.

We used this method in 20 formalin-fixed tissue specimens. The vessels were clearly observable through to the peripheral areas, and leakage from the injected artery was minimal.

This new agent has several beneficial characteristics: it is X-ray impermeable, is durable in the face of chemical insult, and allows for easy visual observation. The injected tissue can be studied for X-ray film examination, tissue clarification, and gross anatomical dissection. Additionally, this method can be applied to both fresh and formalin-fixed tissue. We consider that this method has the potential to expand the applications of injection studies.

Key words cadaver injection study, latex injection, latex–magnetic fluid solution, magnetic fluid, magnetic induction

INTRODUCTION

Vascular injection studies are essential for gross anatomical research of the vascular system. Although various injection methods have been proposed, they differ in terms of the contrast media and agents used, which include barium sulfate and gelatin [1], colored latex [2, 3], latex and barium [4], lead oxide with gelatin [5, 6], and silicone rubber (Microfil; Flow Tech Inc., South Windsor, CT) [7, 8]. These vascular agents are usually injected into fresh cadavers. For whole-body injection, tubes are inserted into large arteries such as the common carotid arteries and femoral arteries, and a large quantity of contrast media is injected using an electric pump or syringe. The systemic injection method is technically easy to perform, and stable results can be obtained without uneven distribution of the vascular agent. However, a large amount of contrast media and a large-scale apparatus are needed. Additionally, the number of cadavers available for such studies is limited. On the other hand, local injection studies are usually performed using resected specimens taken from preserved cadavers. Some of the difficulties associated with these studies include the small caliber, hard-
ness, and embrittlement of arteries secondary to the body-preservation process. However, fixed cadavers are easier to use for research in most medical schools because cadavers are available for anatomical dissection courses for medical students in these facilities. The ability to inject a vascular agent into tissue resected from a preserved cadaver would be greatly advantageous because tissue samples would be easily available and less vascular agent would be required. We have therefore developed a novel injection method that uses the power of magnetic attraction to induce the vascular agent to move through the vasculature, and can be applied to both fresh and fixed tissue specimens.

MATERIALS AND METHODS

This study was performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). We used 20 tissue samples from formalin-fixed cadavers: six sides of the latissimus dorsi muscle through the thoracodorsal artery, six sides of the rectus abdominis muscle through the inferior epigastric artery and superior epigastric artery, four sides of the pectoralis major muscle through the thoracoacromial artery, and four sides of the soleus muscle through the popliteal artery (Table 1).

Latex–magnetic fluid solution

We obtained 500 ml of latex (S-500; Regitex, Atsugi, Kanagawa, Japan) and 50 ml of magnetic fluid with a saturation magnetization of 46.6 mT (DS-50; Sigma Hi-Chemical, Chigasaki, Kanagawa, Japan) (Fig. 1). We poured the same weights of latex and magnetic fluid into a beaker. The original color of the latex is milky white and that of the magnetic fluid is black. We mixed the two fluids well until the solution became a uniform black color. Although we did not add water to the solution, the viscosity can be adjusted if needed by adding distilled water.

Cannulation of the arteries

Arteries in the tissue were identified and dissected to about 1 to 2 cm under a surgical microscope (×5). The inner diameter of the arteries was used to guide selection of an adequately sized external cylinder of an intravenous indwelling needle (Angiocath; Becton Dickinson Infusion Therapy Systems Inc., Sandy, UT). The external needle was then inserted into the artery, which was ligated with a nylon string with the needle to prevent extraction.

Latex injection and magnetic induction

The latex–magnetic fluid solution in the beaker was suctioned into a syringe, and the syringe was con-

TABLE 1.
The subject of the study and the evaluation method
We used 20 tissues from formalin-fixed cadavers and examined the description of the arteries in two ways: gross anatomical dissection and radiograph with gross anatomical dissection.

| Number of fluid injection | Gross anatomical dissection | Gross anatomical dissection and radiograph |
|---------------------------|-----------------------------|-------------------------------------------|
| Latissimus dorsi muscle (Thoracodorsal artery) | 6 | 3 | 3 |
| Rectus abdominis muscle (Superior epigastric artery and Inferior epigastric artery) | 4 | 2 | 2 |
| Pectoralis major muscle (Thoracoacromial artery) | 6 | 3 | 3 |
| Soleus muscle (Popliteal artery) | 4 | 2 | 2 |
| Total | 20 | 10 | 10 |

Fig. 1. Latex and latex–magnetic fluid solution
The white liquid on the left side is the latex magnetic fluid, and the black liquid on the right side is the latex-magnetic solution.
connected to the needle. The solution was then gradually injected into the artery until resistance was felt. The injection was stopped temporarily, and a permanent neodymium magnet (N38; 20 × 10 × 2 mm) was used to attract the solution toward the peripheral region; 20 pieces; surface inductive flux, 151 mT [1535 Gauss] each; absorption power, 2.051 kgf each) obtained from RKC Instrument Inc. (Tokyo, Japan). The magnetic force was applied by gently stroking the magnet toward the direction of the arteries (Fig. 2). The strength of the magnetic force was inversely correlated with the distance; thus, it is most effective to stroke as closely to the tissue as possible. After the solution had moved to the peripheral area, the injection was resumed. The latex injection and magnetic application were repeated until no further solution could be injected. The time of the injection, from the cannulation of the needle to the magnetic induction, was about 10 minutes per vessel.

Curing the latex solution

Latex cures rapidly with the addition of dehydrated ethanol. Therefore, we soaked the latex-injected tissue in 99% ethanol for 1 day.

RESULTS

We divided the 20 tissue samples into two groups. Each group contained 10 tissues, consisting of three latissimus dorsi muscles, three rectus abdominis muscles, two pectoralis major muscles, and two soleus muscles. The first group was examined by gross anatomical dissection (Fig. 3) and the second group was examined by radiograph and gross anatomical dissection. The radiograph was taken under the following conditions: 50 mV, 125 mA, and 0.12 s. Injection of the agent was successful in all 20 specimens, and the magnetic force succeeded in moving the agent to the peripheral areas (Table 1, Fig. 4).

DISCUSSION

The most difficult problem encountered when performing an injection study using tissue removed from a fixed cadaver is leakage of contrast media from the injected part. When contrast media is injected with the aim of filling the peripheral arteries, the contrast media often leaks from the injected part because of excessive local pressure. Once leakage occurs, the injection pressure decreases and the contrast media cannot reach the peripheral area; the injection thus ends in failure. Therefore, a method that does not involve the application of excessive pressure to the injected part is ideal for an injection study. We have developed a novel method that does not depend on high injection pressure. We used a combination of injection pressure and magnetic power to fill a cadaver artery with contrast media. This method requires a lower injection pressure than the conventionally used injection method and can reduce the possibility of leakage. To the best of our knowledge, this is the first method to use magnetic
power to lead contrast media to the periphery of a tissue specimen.

Magnetic fluid is not in widespread use in the field of anatomy. It is a solid–liquid mixed-phase fluid in which fine magnetic particles are stably dispersed. Magnetic fluid was first developed by Dr. Papell of NASA, who obtained a US patent (3215575) in 1965 for the purpose of creating a magnetized liquid to lead liquid fuel for space rockets in gravity-free space [9]. Magnetic fluid is now readily available for common use and is often used to demonstrate magnetic force in science classes. Magnetic fluid is also used in the medical field; for example, it may be used as a contrast agent for magnetic resonance imaging or as a colloidal mediator for magnetic hyperthermia in the treatment of cancer [10, 11]. We applied this unique characteristic of magnetization to the field of anatomy. The magnetic fluid used in the present study is made of magnetite (Fe₃O₄; 40%-60%) and isoparaffin (CₙH₂n₊₂; 40%-60%). This material is insoluble in water. We mixed this magnetic fluid in latex. The latex is originally a white milky sap when it is obtained by tapping rubber trees. After the development of chloroprene rubber, it becomes a fluid in which polymers are stably dispersed in an aqueous medium. Both magnetic fluid and latex are colloidal dispersions. These two materials mix well without any separation.

It is generally known that the magnetic force is inversely proportional to the square of the distance. This means that the magnetic force becomes dramatically weaker when the distance between the permanent magnet and the contrast agent increases. We should therefore place the permanent magnet as close to the contrast agent as possible when attracting the agent to the peripheral area. The method described herein is more suitable for relatively thin tissues that have been removed from the body, such as the skin, subcutaneous tissue, muscle, and other relatively thin tissues; it is not effective for thick tissues such as the liver or brain. We have performed this method for 20 tissue specimens obtained from formalin-fixed cadavers, and the agent was effectively injected to the peripheral areas in all cases. Gross anatomical dissection, tissue clarifying (Fig. 3), and radiography (Fig. 4) were per-

Fig. 3. Combination picture of the injected tissue
The left side is the front and the right side is the rear of the same specimen. The left rectus abdominis muscle was removed from a formalin-preserved cadaver, and the fluid was injected into the stumps of the inferior epigastric artery and superior epigastric artery. The fluid was induced to the peripheral area by the magnet. The rectus abdominis muscle was soaked in 3% KOH solution for 4 days to create a semi-transparent specimen. The picture was taken on the light viewer for a transparent film.

Fig. 4. Radiographic findings of injected tissue
The agent was injected into the left latissimus dorsi muscle through the thoracodorsal artery. The injected vessels were well visualized to the peripheral area.
formed to observe the vessels in the tissue. The injected tissues were contrasted well enough for the small vessels to observe macroscopically, and sufficient findings were obtained. The injected vessels are easy to observe visually and treat because of the black color and elastic character. Furthermore, the magnetic fluid is impermeable to X-rays, making it visible on radiographs. We have adopted this method only for arteries. Veins usually can be identified easily because they contain coagulated blood in the cavity and appear black and dark blue in preserved cadavers. However, this method may be better suited for veins or lymphatic vessels, which have thin walls, because of its low injection pressure. We plan to adapt this method to these vessels in the future.

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DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST: The authors declare that they have no conflict of interest.

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