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基于猪油的尸体血管灌注技术的问与答

Questions and answers about lard-based vascular perfusion technology in cadavers

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问：我们最初使用什么灌注液进行尸体血管灌注？

答：我们最初使用经典的乳胶尸体血管灌注法。但解剖过程中漏胶严重，解剖体验很差，实验效率很低。基于此，我们认为这一经典的灌注方法是有一定技术门槛的。

问：怎么想到要选用温敏的灌注液？

答：复习经典的解剖技术书籍[1]，温敏灌注液首次进入我们的视野并引起我们的兴趣。文献复习发现已经有明胶灌注尸体血管的成功案例[2,3]。我们曾经使用这一方法做了部分实验，结果表明明胶需要配制，比较麻烦。我们也注意到其他温敏灌注液，但发现熔点较高，可能导致血管损伤。基于此，我们尝试寻找更理想的温敏灌注液。

问：基于猪油的尸体血管灌注技术是如何发现的？

答：基于猪油的尸体血管灌注技术的发现纯属巧合。夏天，猪油在室温下呈液态，放入冰箱不久就固化了，而且具备一定的强度。我们认为从温度控制、固化后强度这两个方面看，猪油似乎是很理想的尸体血管灌注剂。复习文献，未见相关报道，于是我们首次使用并报道了这一技术[4]。

问：基于猪油的尸体血管灌注技术的步骤是什么？

答：该技术步骤比较简单，主要注意温度控制，30-40 ° C 下，将猪油和油性染料根据个人喜好混合，混匀。血管置管、固定后，将猪油-油性染料混合物注入血管，将灌注后的标本置入放有冰水混合物的泡沫箱约 3-4 小时。后续解剖操作在低温环境（10-15℃）下完成[4]。

问：基于猪油的尸体血管灌注技术的可靠性、安全性怎么样？

答：我们绝大部分的实验均采用该技术，目前已经发表 11 篇论文，表明这一技术的可靠性和可重复性非常高。自从使用这一技术，我们的实验效率大增。而且，该技术所有步骤均不涉及任何有害物质，所以绿色环保、人畜无害[4-14]。

问：为什么有的文章中用作者自己提炼的猪油[4,8]，而有的文章用的猪油是超市购买的？

答：我们早期的解剖研究中，发现猪不同部位的脂肪组织硬度是不一样的，我们怀疑从较硬的脂肪组织中提炼的猪油可能比从较软的脂肪组织中提炼的猪油更硬，所以我们早期的文章中用我们自己提炼的猪油。在一次实验中，我们自己提炼的猪油用光了，只能从超市购买猪油，结果发现购买的猪油硬化后强度很理想。所以我们后期的文章均使用超市购买的猪油，这也进一步简化了这一技术的步骤。

问：为什么有的文章中使用电动加压装置灌注猪油[8,11]，而有的文章中是手工灌注猪油[4-7,9,10,12]？

答：早期，为了实验的可重复性更高，我们使用了可以设定具体灌注压力的电动加压装置。电动加压装置在灌注下肢血管时有优势，但在灌注离体肝脏、肾脏、心脏等器官时根本用不到，而且，我们也尝试手工灌注下肢血管，完全能达到理想的灌注效果，所以我们后续的实验均采用手工灌注。这也进一步降低了我们对实验设备的依赖，简化了这一技术的步骤。

问：猪油-油性染料的配置比例有无要求？

答：猪油-油性染料的配置比例无特殊要求，完全根据实验者自身对颜色的喜好，这也进一步简化了这一技术的步骤

问：为什么有的文章中强调这一技术是在冬天使用的？[5,8,11,12]

答：这一技术是我们在夏天发现的，使用过程中还是有些麻烦的，比如解剖操作时标本要放在冰上，增加了实验的难度，实验者需长时间将双手暴露于低温环境，实验体验也不理想。然而，当我们在冬天进行实验时，我们发现在室温下，灌注的猪油呈固态，硬度满意，大大简化了这一技术的步骤。实验效率和实验体验都很满意。所以我们在文章中特别讨论了这一发现。这一发现对于有标准实验室的同行，也有指导意义，就是解剖操作时温度可控制在 10-15° C 左右。

问：为什么没有将这一技术与其他灌注技术进行比较？

答：这主要是实验的目的和实验条件决定的。经典乳胶灌注法往往用于长时间保存的标本，是应用最广泛的方法，但是，这一方法往外是在标准实验室完成的，不适合居家科研。我们的实验目的是居家科研，实验条件有限，标本用后即弃，血管灌注液的硬度无特别要求，只要解剖过程中不出现漏液现象即能满足实验要求。虽然也有其它温敏灌注液，但要么熔点较高，容易导致血管损伤，要么需要配置，操作有些繁琐。所以这些技术并不是我们的选择。我们的经验表明，基于猪油的尸体血管灌注技术似乎是专为居家科研量身定制的技术。

问：该技术能显示毛细血管吗？

答：该技术完全可以显示包括毛细血管在内的各级动脉。在我们早期研究中，该技术可以清楚显示骨膜表面的毛细血管[4]，我们目前申请专利的第二个核心技术也充分证实这一点。已有报道表明同类的温度敏感型灌注液（比如明胶）可以用于微循环的研究[3]。

问：以该技术为例，我们该如何充分发挥温度敏感型灌注液在尸体手术训练中的优势？

答：要根据研究目的选择合适的温度，比如，从血管解剖角度，我们应该在低温(10-15° C)下进行操作，这样解剖视野清晰；从模拟临床的角度，我们应该在高温(30° C 左右)下操作，虽然视野不理想，但的确最大程度上模拟了临床实际[15]。

问：如何利用该技术缩短尸体标本准备的时间？

答：我们早期的研究表明，尸体标本长时间放置后组织会硬化，可能会得出错误结论[9]。该技术本身仅需数小时即可实现猪油的硬化，但我们发现还可以进一步压缩硬化时间，比如，以单纯表浅组织为研究对象时，将该处与冰接触十几分钟即可实现猪油硬化；再比如，以游离脏器为研究对象时，可以将脏器游离，灌注后在冰水混合物中浸泡十几分钟即可实现猪油硬化[15]。

问：该技术对染料颜色有无特殊要求？

答：我们早期研究中，主张染料颜色选择根据个人喜好，但目前我们建议使用黑色染料用于在体解剖研究，因为黑色染料便于与周围红色肌肉形成鲜明色差。我们还建议，对于需要离体展示的血管，最好使用红色染料，因为红色血管离体后视觉效果好。

问：该技术的技术要点会定期更新吗？

答：我们会定期总结我们使用该技术过程中的心得体会更新于此。

Questions and answers about lard-based vascular perfusion technology in cadavers

Question: What perfusion material did we initially use for vascular perfusion in cadavers?

Answer: We initially used the classic latex vascular perfusion method. However, during the dissection process, severe latex leakage occurred, resulting in very poor dissection experience and low experimental efficiency. On this basis, we believe that this classic perfusion method has a certain technical threshold.

Question: How did we come up with the idea of choosing a temperature-sensitive perfusion material?

Answer: Reviewing the classic books on anatomical technology[1], temperature-sensitive perfusion material first came into our view and attracted our interest. A literature review revealed successful use of the gelatin infusion method in cadavers[2,3]. We previously conducted experiments using this method, and the results revealed that the preparation of gelatin was rather difficult. We also noticed other temperature-sensitive perfusion materials but reported that they had higher melting points and might cause vascular damage. On this basis, we attempted to find a more ideal temperature-sensitive perfusion material.

Question: How was lard-based vascular perfusion technology discovered in cadavers?

Answer: The discovery of this technology was purely coincidental. In summer, lard is liquid at room temperature and solidifies shortly after being placed in the refrigerator, and it also has a certain strength. Judging from the perspectives of temperature control and strength

after solidifying, the lard seems to be an ideal vascular perfusion material. A brief literature review revealed no relevant reports on lard perfusion technology; thus, we used and reported this technology for the first time[4].

Question: What are the steps of lard-based vascular perfusion technology in cadavers?

Answer: The technical steps are relatively simple. The key is to pay attention to temperature control. At approximately 30–40°C, the dye was added to the lard according to personal preference. The mixture of the dye and the lard was stirred with a stripping rod. After vascular catheterization and fixation, a mixture of lard and dye is injected into the blood vessel. The infused specimens are then placed in a foam box containing a mixture of ice and water for approximately 3 to 4 hours. The subsequent anatomical operations were conducted in a low-temperature environment (10-15℃)[4].

Question: What are the efficiency and safety of lard-based vascular perfusion technology in cadavers?

Answer: The vast majority of our experiments have adopted this technology. To date, 11 papers have been published, indicating that the reliability and repeatability of this technology are extremely high. Since this technology was used, the efficiency of our experiments has greatly increased. Moreover, all the steps of this technology do not involve any harmful substances, so it is environmentally friendly[4-14].

Question: Why do some articles use lard refined by the author themselves[4,8], while others use lard purchased from supermarkets?

Answer: In our early anatomical studies, we reported that the hardness of adipose tissue in different parts of pigs varies. We suspected that lard extracted from harder adipose tissue might be harder than that extracted from softer adipose tissue. Therefore, in our early articles, we used lard extracted by us. In an experiment, the lard we refined ran out, and we could only buy lard from the supermarket. As a result, we found that the lard we bought had an ideal strength after hardening. Therefore, in our later articles, we used lard purchased from supermarkets, which further simplified the steps of this technology.

Question: Why do some articles use electric pressurization devices to inject lard[8,11], while others use manual injection[4-7,9,10,12]?

Answer: In the early stage, to enhance the repeatability of the experiment, we used an electric pressurizing device that could set a specific perfusion pressure. An electric compression device has advantages when it is used to infuse lower extremity blood vessels, but it is completely useless when it is used to infuse isolated organs such as the liver, kidney and heart. Moreover, we attempted manual perfusion of lower extremity blood vessels, which could completely achieve the ideal perfusion effect. Therefore, all our subsequent experiments adopted manual perfusion. This further reduces our reliance on experimental equipment and simplifies the steps of this technology.

Question: Are there any requirements for the configuration ratio of lard to dyes?

Answer: There are no special requirements for the configuration ratio of lard to dyes. It is entirely based on the experimenter's own preference for color, which further simplifies the steps of this technology.

Question: Why do some articles emphasize that this technology is used in the winter[5,8,11,12]?

Answer: This technology was discovered by us in the summer. There are still some problems associated with its application. For instance, during the dissection operation, the samples need to be placed on ice, which increases the difficulty of the experiment. The experimenters have to expose their hands to the low-temperature environment for a long time, and the experimental experience is not ideal either. However, when we conducted the experiments in the winter, we found that at room temperature, the injected lard was solid and had satisfactory hardness, greatly simplifying the steps of this technology. Both the experimental efficiency and the experimental experience are very satisfactory. Therefore, we discuss this discovery in particular in the article. This discovery also has guiding significance for colleagues with standard laboratories; that is, the temperature during anatomical operations can be controlled at approximately 10–15°C.

Question: Why do we fail to compare this technology with other perfusion technologies?

Answer: This is determined mainly by the purpose of the experiment and the experimental conditions. The classic latex perfusion method is often used for specimens that have to be preserved for a long time and is the most widely applied method. However, this method is usually carried out in a standard laboratory and is not suitable for home-based research. The purpose of our experiment is home-based scientific research. Our experimental conditions are limited. The samples are disposable after use. There are no special requirements for the hardness of the vascular perfusion material. As long as there is no leakage during the

dissection process, the experimental requirements can be met. Although there are other temperature-sensitive perfusion materials, they can easily cause vascular damage, or they need to be prepared, and the operation is somewhat cumbersome. Therefore, these technologies are not our choice. Our experience shows that lard-based vascular perfusion technology in cadavers seems to be tailor-made for in-house-based research.

Question: Can this technology display capillaries?

Answer: This technology can fully display arteries at all levels, including capillaries. In our earlier research, this technology clearly displayed the capillaries on the surface of the periosteum [4]. The second key technology we are currently applying for a patent also fully confirms this point. It has long been reported that similar temperature-sensitive perfusion fluids (such as gelatin) can be used in the study of microcirculation [3].

Question: How can we fully leverage the advantages of temperature-sensitive perfusion fluid in cadaveric surgery training?

Answer: The appropriate temperature should be selected on the basis of the research purpose. For instance, from the perspective of vascular anatomy, operations should be conducted at a low temperature (10-15 °C) so that the anatomical field of view is clear. From the perspective of simulating clinical practice, we should operate at high temperatures (around 30 °C) . Although the field of vision is not ideal, it does simulate clinical reality to the greatest extent [15].

Question: How can this technology be utilized to shorten the time for preparing cadaver specimens?

Answer: Our earlier research indicated that the tissues of cadaver specimens harden after long-term storage, which might lead to incorrect conclusions [9]. This technology itself takes only a few hours to harden lard, but we have reported that the hardening time can be further reduced. For instance, when only superficial tissue is taken as the research object, exposing that area to ice for approximately ten minutes can achieve lard hardening. For instance, when free organs are taken as the research object, they can be free and then soaked in a mixture of ice and water for approximately ten minutes to harden the lard [15].

Question: Does this technology have any special requirements for the color of dyes?

Answer: In our early research, we advocated that the choice of dye color should be based on personal preference. However, we currently recommend the use of black dye for in vivo anatomical studies because black dye is conducive to creating a distinct color contrast with the surrounding red muscles. We also suggest that for blood vessels that need to be displayed in vitro, it is best to use red dye, as red blood vessels have better visual effects after being displayed in vitro.

Question: Will the key points of this technology be updated regularly?

Answer: We will regularly summarize our experiences and insights gained during the use of this technology and update them here.

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