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REVIEW ARTICLE

Reinforcement and reapproximation of the aortic stump during surgery for acute aortic dissection

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Abstract
Anastomosis of the fragile aortic wall in patients with acute aortic dissection presents a challenge to cardiovascular surgeons. Reinforcement of the stump is a key to accomplishing successful anastomosis. Surgical glues such as gelatin–resorcin–formalin (GRF) glue and Bioglue are easy to use and have radically changed the process of the reinforcement and reapproximation. However, as surgical glues have been associated with disadvantages such as tissue necrosis, enthusiasm for their use has waned. In this review, we discuss the various methods for reinforcement and reapproximation of the aortic stump during operations for acute aortic dissection, mainly outside the category of surgical glues.

Keywords Acute aortic dissection · Surgical techniques · Anastomosis · Graft replacement

Introduction

The key to performing safe emergency repair of Stanford type A acute aortic dissection is to achieve secure anastomoses with minimal bleeding. The dissected wall is usually fragile and requires reinforcement to create the anastomosis. In 1962, Hufnagel et al. [1] described a method of reapproximation using simple running sutures at the stump of the dissected ascending aorta. This simple technique of reapproximation was improved with a reinforcement. A standard technique that is still practiced today involves applying Teflon felt strips to reinforce the dissected aortic wall [2]. Since the 1970s, a range of surgical glues have been introduced for aortic wall reapproximation and reinforcement. Surgical glues such as gelatin–resorcin–formalin (GRF) glue and Bioglue are easy to use and have changed the process of reapproximation. However, as their use has been associated with tissue necrosis and other sequelae, caution has arisen. Moreover, the importance of non-leaky anastomoses has been highlighted to prevent downstream residual dissection [3]. We review the methods currently being used for reinforcement and reapproximation of the aortic stump during operations for acute aortic dissection.

Sandwich technique using Teflon felt strips

Teflon, also known as polytetrafluoroethylene (PTFE) felt strips are used frequently for reinforcing the anastomotic site of the aorta in cardiovascular operations. At the stump of the dissected aorta, the adventitia and intima are completely separated, but these layers are thin and fragile on their own. The dissected layers should be fixed firmly together at the site of anastomosis; therefore, Teflon felt strips should be used on both the outside and inside of the aortic wall during reinforcement. Cachera et al. [4] described how to apply felt strips at the aortic stump, indicating that wider strips should be used, including below the level of the coronary orifices. Tang et al. [5] subsequently reported the surgical results of using a modified shape of Teflon strip, covering the non-coronary sinus. The use of Teflon felt strips is not completely safe, as the inside strip can cause aortic narrowing and pressure gradients [6]. Moreover, felt strips inside the aorta at the proximal anastomosis can be overturned and stiffen, causing aortic stenosis [7]. Teflon felt strips are also known to contribute to embolism formation [8], as mobile thrombi on internal felt strips have been reported to cause cerebral infarction [9]. Numerous reports published between 1990 and 2016 describe hemolysis being caused by felt strips

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[10–16]. Despite these publications, this sandwich technique was still utilized until recently.

Modifications to the sandwich technique

A wide range of modifications to the original sandwich technique have been reported. Many of the complications described were related to the Teflon material itself. Gaeta reported a case in which Dacron (polyethylene terephthalate) was used instead of a Teflon strip [17]. They noted that as Dacron is part of the graft used for replacement of the dissected aorta, its use incurs no additional cost. Dacron grafts are thinner than Teflon felt, leading to fewer complications. Kan et al. also utilized Dacron grafts instead of Teflon felt, as the inner material [18]. Moreover, they used interrupted sutures instead of a running suture, and the graft was inserted telescopically at both the proximal and distal anastomoses. Interrupted sutures were found to decrease the cutting force on the aortic wall caused by continuous running sutures. The main difference is that no additional material was used, besides the main inner Dacron graft.

Rignano et al. [19] reported an interesting method in which an inverted short segment Dacron graft was inserted and anastomosed 0.5 cm above the aortic valve, using an outer Teflon felt strip. The everted graft was pulled out after suturing. Rignano et al. reported five cases and Inoue et al. reported [20] over 50 cases of using the same technique. Inoue et al. used a shorter Dacron graft and performed a leak test with an antegrade cardioplegia infusion through the graft. Tamura et al. [21] described a "turn-up" technique for distal anastomosis, including a sandwich with the everted end of the Dacron graft and an outer Teflon felt strip. The final shape of the anastomosis was the same as that reported by Rignano and Inoue. Kan et al., who described the telescope anastomosis with interrupted sutures, later reported [22] switching to this "inverted prosthesis method" at the distal anastomosis. Rylski et al. [23] then described a simple method of "graft telescope inversion" for anastomosis without using any inner material, as the tip of the inserted tube graft provided inner reinforcement. However, this method of suturing is potentially very difficult; thus, it is recommended that this technique be used cautiously for all aortic anastomoses.

Xenopericardium is common material used in the field of cardiovascular surgery. Nomura et al. [24] described a sandwich technique using xenopericardium with GRF glue inside the false lumen as an adjunct. Fleck et al. [25] reported a modified sandwich technique in 2003, in which Teflon felt was used on the outside and bovine pericardium was used as a cap for the dissected stump. The cap covered the inner and outer surfaces of the aortic wall, acting in the same way as the sandwich technique. Sealing the cap with xenopericardium improved hemostasis and reduced bleeding. Minato et al. [26] utilized autologous pericardium as a reinforcement for the cap, harvesting adventitia from the resected aortic wall and using a strip of adventitia for anastomotic reinforcement. They found that this adventitial overlay method resulted in less bleeding from the anastomotic gap and needle holes, and that less string tension was generated against the aortic wall because of the soft tissue in between. They concluded that this may achieve long-term stability without the formation of anastomotic pseudoaneurysm or new intimal tears.

Adventitial inversion technique

Before Minato et al. utilized autologous adventitia to reinforce the anastomosis, Floten et al. was the first to investigate the use of adventitia for reinforcement [27]. They utilized the "adventitial inversion technique" for distal anastomosis in ascending aortic replacement by trimming back the margin of the intima 1 cm distal to the adventitial resection line. The redundant adventitia was then inverted into the aortic lumen and tacked to the luminal surface of the intima with a horizontal 6–0 polypropylene mattress suture. Consequently, the stump was covered entirely with adventitia. This technique may also be applied in proximal anastomoses and for Stanford type B dissections [28]. Tanaka et al. [29] concluded that this adventitial inversion technique provides excellent immediate hemostasis and facilitates thrombotic closure of the proximal and distal false lumens for the treatment of acute aortic dissection. Oda et al. [30] subsequently performed a small-scale study of this adventitial inversion technique and found that the false lumen was thrombosed in 78.8% of patients treated with adventitial inversion versus 47.9% of patients treated with the classic sandwich technique using Teflon felt strips ($P < 0.05$). They applied the felt strip outside in addition to the adventitial inversion technique.

Rylski et al. [31] reported their experience of performing telescope anastomosis using this adventitial inversion method. Ohata et al. [32] also described their experience of using a graft turn-up procedure alongside this adventitial inversion technique. Neri et al. [33] reported performing this technique in combination with GRF glue.

Neomedia

Stump reinforcement in patients with acute aortic dissection can be performed not only using the sandwich strategy, but also by using anchor material inside the aortic wall. Koster et al. [34] described a method in which a Teflon felt strip was placed inside the aortic wall between the adventitia and intima. The felt was used as neomedia in the ascending

aorta and the adventitia and intima were oversewn with polypropylene sutures at the edge of the stump. This neomedia technique was refined by Bavaria et al. [35], who included tailored felts within the false lumen at the sinus of Valsalva during proximal anastomosis. They also applied Bioglue in recent cases and this was not considered a risk factor for proximal reoperation [36]. Their results indicated that the sinus of Valsalva could be preserved in major acute aortic dissection [37]. Nakajima et al. [38] reported a different neomedia method, using a fabric sheet presoaked in fibrinogen solution. The fabric sheet was composed of 0.61-mm thick knitted polyester (Bard Sauvage Fabric, Tempe, AZ). Fibrin sealant patches (FSPs) were also utilized for neomedia. TachoSil® (Takeda, Konstanz, Germany), a commercial collagen matrix coated with fibrinogen and thrombin, was used as the FSP [39]. Two Tachosil® matrices of the same size were irrigated with cold saline and combined, leaving the fibrinogen/thrombin coated layers dry and facing outward. This sandwiched Tachosil®-Matrix was then placed between the dissected aortic tissue layers. Lisy et al. concluded that this technique is feasible, safe, and effective for repairing dissected aortic tissue. Ohira et al. [40] subsequently combined the thin fabric sheet and FSP together into one neomedia.

Conclusions

The use of GRF glue and Bioglue is easy and effective for stump reinforcement and reapproximation in patients with acute aortic dissection. Adjuncts such as Teflon felt strips were considered outdated upon the advent of surgical glues; however, adjuncts are currently experiencing a return to the fore, as a result of the limitations of using surgical glue. Every technique has its pros and cons and there is no perfect solution to performing safe anastomosis during surgery for acute aortic dissection. The strategies described in this article should be considered when planning safe repair of acute aortic dissection.

Compliance with ethical standards

Conflict of interest Kenji Minatoya and Nobuhisa Ohno have no conflicts of interest to declare.

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