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ORIGINAL ARTICLE

Comparison of Vascular Ring Connector and Conventional Suture Technique in the Surgical Management of Acute Type A Aortic Dissection

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Background: The aim of this study was to examine the utility of the vascular ring connector (VRC) and compare the clinical outcomes to conventional suture technique in the operation for acute type A aortic dissection (AAAD). **Methods:** We retrospectively enrolled 64 consecutive patients (mean age 57.4 ± 12.7 years, range 24–82 years) with AAAD who underwent emergent surgery in our institution from September 2010 to November 2014. Patients were divided into VRC group (55 patients) and conventional suture group (nine patients) based on the use of VRC during the operation. The preoperative characteristics, operative variables, and postoperative outcomes were collected and analyzed. **Results:** Male patients predominated in both groups. The mean times of cardiopulmonary bypass and aortic cross-clamp were 200.1 ± 99.9 and 193.6 ± 54.7 min (P = 0.425) and 107.5 ± 56.2 and 112.3 ± 40.8 min (P = 0.404) in the VRC group and suture group, respectively. There were more blood transfusions within 24 h (1513.3 ± 949.2 vs. 841.8 ± 801.1 ml) and more mediastinal drainage amount (1314.4 ± 650.3 ml vs. 942.1 ± 527.2 ml) in the suture group than in the VRC group. In the VRC group, 36.3% of patients did not require blood transfusion. Moreover, the pumping time and cardiac ischemic times were longer in the one-VRC group than in the two-VRC group. Operative mortality did not differ between the two groups (10.9% in VRC and 11.1% in suture group, P = 0.985). No dislodgement of VRC during or after operation and no bleeding from sutureless anastomosis site were noted. **Conclusion:** Use of VRC is associated with equivalent operative mortality and morbidity compared to suture group in patients with AAAD undergoing an emergent operation. This study demonstrates the clinical safety and efficacy of VRC in reducing the need of blood transfusion within 24 h and mediastinal drainage within 72 h. However, further randomized studies and long-term surveillance of the use of VRC in AAAD are still mandatory.

Key words: Conventional suture, vascular ring connector, acute type A aortic dissection, surgical outcomes

INTRODUCTION

Acute type A aortic dissection (AAAD) is a serious and potentially catastrophic cardiovascular emergency that can result in sudden death. The mortality rate within 2 weeks approaches 75% in patients with undiagnosed AAAD.[1] Despite

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recent advances in surgical techniques and perioperative management, the in-hospital mortality rate is still high, with about 23%–26%, from the International Registry of Acute Aortic Dissections data.[2] In addition to critical preoperative hemodynamic status and organ malperfusion, the fragility of the aortic tissue in AAAD makes suturing of the vascular prosthesis to the aorta difficult and may result in bleeding from anastomosis site and prolonged pumping time, which may complicate with coagulopathy and needs a massive blood transfusion. Thus, minimization of the bleeding from the anastomosis sites and achieving an adequate hemostasis in the operation of AAAD are crucial for patients' outcomes. Vascular ring connector (VRC) (Vasoring, Sunwei Technology Co., Taipei, Taiwan, Republic of China) was designed as an intraluminal biocompatible titanium alloy to fix the aorta together with the vascular prosthesis with tapes outside the aorta, creating a sutureless anastomosis.[3] Based on previously published papers, Wei *et al*. demonstrated that use of VRCs in surgical repair for aortic dissection might reduce bleeding risks and provide satisfactory early and midterm results.[3,4] The primary aim of our study was to compare the clinical outcomes between VRC and conventional suture in patients undergoing an emergent operation for AAAD.

METHODS

The Institutional Review Board approved this retrospective observational study, and the approval included a waiver of informed consent (TSGH IRB 1-105-05-103).

Study patients

A retrospective review of patient records and imaging studies was conducted in 64 patients with AAAD undergoing open surgery at our institution from September 2010 to November 2014. During the operation, patients undergoing the surgery using at least one VRC were categorized as the VRC group. Demographic and clinical data, including information on the patient's prior medical history, cardiac risk factors, operative details, and duration of postoperative Intensive Care Unit (ICU) stay and hospital days, were collected and analyzed. Eight patients (seven in the VRC group and one in the suture group) who expired within 72 h after the operation were excluded from this study.

Surgical procedure

Surgery for AAAD was performed through sternotomy in both groups of patients, and the operation was done with the utilization of cardiopulmonary bypass (CPB). Sites for arterial and venous cannulation were chosen according to the anatomical and pathological findings on computed tomography. CPB was established after total heparinization (300 IU/kg) using a roller pump and hollow-fiber membrane oxygenator, with pump flow rates of 2.0–2.5 L/min/m^2 to maintain a perfusion pressure of approximately 65 mmHg. After establishing the CPB and cooling the circulation down to 32°C, the distal ascending aorta was cross-clamped, and the ascending aorta was incised to assess the presence of an intimal tear and the anatomy of the aortic root and the aortic valve. Cardiac arrest was achieved by infusing cardioplegic histidine-tryptophan-ketoglutarate solution (HTK; Custodiol) into the coronary orifices directly and/or retrograde cardioplegic solution infusion. The decision regarding the extent of reconstruction and the use of VRC or conventional suture technique was made intraoperatively by the surgeon and supported by intraoperative evaluation of dynamic aortic valve and root properties by transesophageal echocardiogram and the fragility of the aortic tissue. The surgical technique used for VRC has been described in detail in Dr. Wei's previously published paper.[2] In general principle, the intimal tear and dilated segment of the aorta in the ascending aorta, aortic root, and aortic arch were resected. We performed aortic root operations based on at least one of the following conditions: intimal tear in the aortic root, extensive involvement of coronary arteries, rupture of the aortic root, and an aortic root diameter of 45 mm or greater. The ascending aorta distal to the sinotubular junction was replaced in all patients with a gelatin-impregnated Dacron graft of appropriate size. The presence of an intimal tear extending into the aortic arch or crossing the clamp area usually addressed the patient to an open distal anastomosis under hypothermic circulatory arrest (HCA). When the entry tear was limited to the aortic root or the ascending aorta, the distal repair was performed either with or without HCA, depending on the surgeon's preference and the use of VRC or conventional suture technique. Three different strategies for cerebral protection were used for an open distal anastomosis: deep HCA, HCA with retrograde cerebral perfusion, and HCA with antegrade cerebral perfusion. Antegrade cerebral perfusion is currently the first-choice adjunct for brain protection during moderate HCA.

After exclusion of the intimal tear and completed reconstruction of the involved aortic segment, CPB was weaned off and adequate hemostasis was achieved, the femoral artery and the subclavian artery were repaired, and the sternal wound was closed after placement of mediastinal drainage tubes.

In the postoperative period, all patients received the postoperative care in the same ICU. Although there are some preferences in different attending surgeons, the general principles and guidelines of postoperative care are similar.

The requirement of a transfusion was considered when the hemoglobin level was <8 g/dL or if a patient exhibited clinical signs indicating the requirement for a higher oxygen carrying capacity. We did not have a set criteria for exploration regarding chest tube blood output. Re-exploration for mediastinal bleeding was based on hemodynamic status and clinical signs, including excessive chest-tube output and hypotension/tachycardia that may be early signs of potential cardiac tamponade. About the respiratory care, the extubation criteria include adequate mentation (Glasgow Coma Scale [GCS] >13, minimal sedation); stable hemodynamic condition on minimal inotropes (e.g. dopamine <5 mcg/kg/min); peripheral O_2 saturation >95% and acceptable arterial blood gas analysis: pH >7.25; PaO_2 >80 mmHg; $PaCO_2$ <60mmHg; PaO_2/FiO_2 >150 on PEEP <5–8 cm H_2O and FiO_2 <0.4–0.5.

Statistical analysis

All statistical analyses were performed using the statistical software SPSS for Windows, version 17.0 (SPSS, Chicago, IL, USA). Descriptive statistics were expressed as a mean ± standard deviation. Student's *t*-test was used to analyze continuous variables, and Chi-square test was used to compare categorical variables between the groups. Statistical significance was assumed if the $P < 0.05$.

RESULTS

Patient profiles

Of the 64 patients, with a mean age of 57.4 ± 12.7 years (range: 24–82 years) and a predominating male gender (n = 42, 65.6%), 55 patients (36 males and 19 females) underwent aortic reconstruction with VRC (VRC group) and nine patients (six males and three females) with conventional suture technique (suture group). The suture group was older than the VRC group (56.1 ± 12.7 years vs. 65.3 ± 11.2 years, $P = 0.022$). Preoperative characteristics of the enrolled patients are summarized in Table 1. The most common medical risk factor was hypertension (84.4%) in our series. The patient demographics and preoperative variables, except age, did not demonstrate significant differences between the VRC and conventional groups.

Operative data

Operative data are reported in Table 2. Simple ascending aortic replacement was the most common procedure in both groups, which was performed in 39 patients (60.9%) in our study group. Aortic valve suspension was performed in 34 patients (61.8%) in the VRC group and in two patients (22.2%) in the suture group. In the VRC group, ten patients underwent aortic replacement with two VRCs for proximal and distal anastomoses, and one VRC was used for distal anastomosis in the remaining 45 patients. Concomitant procedures were more commonly performed in the VRC group (one coronary artery bypass grafting, two femoral-to-femoral arterial bypass operation, and three frozen elephant trunk).

Table 1: Preoperative characteristics

	VRC (n=55)	Suture (n=9)	P
Ages (years)	56.1±12.7	65.3±11.2	0.022
Sex (male/female), %	36 (65.4)	6 (66.7)	0.943
CAD, yes/no (%)	4 (7.3)	1 (11.1)	0.690
HTN, yes/no (%)	45 (81.8)	9 (100)	0.163
DM, yes/no (%)	9 (16.4)	2 (22.2)	0.665
Hyperlipidemia, yes/no (%)	9 (16.4)	1 (11.1)	0.687
Hyperuricemia, yes/no (%)	7 (12.7)	0	0.256
Chronic renal failure, yes/no (%)	9 (16.4)	3 (33.3)	0.226
Marfan syndrome, n (%)	1 (1.8)	0	0.683
Cardiac tamponade, yes/no (%)	15 (27.3)	4 (44.4)	0.295
Moderate to severe AR, yes/no (%)	22 (40.0)	4 (44.4)	0.801
Acute kidney injury, yes/no (%)	13 (23.6)	4 (44.4)	0.190
Cerebral malperfusion, yes/no (%)	9 (16.4)	1 (11.1)	0.687
OHCA, yes/no (%)	3 (5.5)	0	0.472
Preoperative shock status, yes/no (%)	10 (18.2)	3 (33.3)	0.294

AR = Aortic regurgitation; OHCA = Out-of-hospital cardiac arrest; CAD = Coronary artery disease; HTN = Hypertension; DM = Diabetes mellitus; VRC = Vascular ring connector

Table 2: Operative data

	VRC (n=55)	Suture (n=9)	P
Pumping time (min)	200.1±99.9	193.6±54.7	0.425
Cardiac ischemic time (min)	107.5±56.2	112.3±40.8	0.404
Ascending aorta only	37	2	-
AsAo plus hemiarch	6	3	-
AsAo plus total aortic arch	5	0	-
AsAo plus total aortic arch plus proximal third DsAo	1	1	-
Bentall procedure	6	1	-
David procedure	0	2	-
ICU stay (day)	9.3±8.4	11.7±7.4	0.207
Hospital stay (day)	25.3±15.9	23.6±11.1	0.384
24 h blood transfusion (ml)	841.8±801.1	1513.3±949.2	0.013
72 h drainage amount (ml)	942.1±527.2	1314.4±650.3	0.030
Time to extubation (day)	4.1±2.1	7.6±7.6	0.006
Number of blood transfusions (%)	20 (36.3)	2 (22.2)	0.407

AsAo = Ascending aorta; DsAo = Descending aorta; ICU = Intensive Care Unit; VRC = Vascular ring connector

For further analyses, we divided the VRC group into one-VRC group and two-VRC group; the operative data are summarized in Table 3. The pumping time was longer in one-VRC group (210.9 ± 105.3 min) than in two-VRC group (151.3 ± 49.7 min). The mean cardiac ischemic time was also longer in one-VRC group (69.3 ± 40.4 min) than in two-VRC group (116.0 ± 56.0 min). Although not statistically significant, there was a trend of a shorter period of ICU and hospital stay in the two-VRC group. Half of patients in the two-VRC group did not receive any blood transfusion. No bleeding was noted over the VRC anastomosis sites, and no dislodgement of VRCs was observed during or after operation in this series.

Table 3: General surgical results of double rings versus single ring

	Two-VRC (*n*=10)	One-VRC (*n*=45)	*P*
Pumping time (min)	151.3±49.7	210.9±105.3	0.043
Cardiac ischemic time (min)	69.3±40.4	116.0±56.0	0.007
ICU stay (day)	6.8±4.2	9.8±9.0	0.148
Hospital stay (day)	18.7±8.4	26.7±16.9	0.074
24 h blood transfusion (ml)	729.0±816.7	866.8±804.8	0.313
72 h drainage amount (ml)	876.0±312.6	956.8±565.6	0.332
Time to extubation (day)	4.0±3.5	4.1±2.1	0.454
No. of blood transfusions (no.), %	5 (50)	15 (33.3)	0.321

ICU = Intensive Care Unit; VRC = Vascular ring connector

Surgical complications and early outcomes

The mean postoperative ICU and hospital length of stay were not different between the groups. There were more blood transfusions within 24 h (1513.3 ± 949.2 vs. 841.8 ± 801.1 ml) and more mediastinal drainage amount (1314.4 ± 650.3 ml vs. 942.1 ± 527.2 ml) in the suture group than in the VRC group. Re-exploration for mediastinal bleeding was performed in two patients in the VRC group and one patient in the suture group. The operative death occurred in five patients (10.9%) in the VRC group and one patient (11.1%) in the suture group. The causes of death were acute cerebral infarction in three patients, multiple organ failure in two, and septic shock in one patient. The early surgical complications within 30 days and in-hospital mortality rates are listed in Table 4. Of the 64 patients enrolled in this study, only one patient was complicated with a complete atrioventricular (AV) block and was treated with implantation of a permanent pacemaker. The patient was a 72-year-old male who presented to our emergency room with AAAD with right ventricular failure and complete AV block before the operation. Reconstruction of ascending aorta and coronary artery bypass grafting to right coronary artery (RCA) were done. However, complete AV block was still noted, so we implanted the pacemaker 14 days after the initial emergent operation. In this sporadic case, AV block should be attributed to the aortic dissection with the involvement of RCA orifice and subsequent AV node injury.

Table 4: Early surgical complications within 30 days and in-hospital mortality

	VRC (*n*=55), %	Suture (*n*=9), %	*P*
Acute cerebral infarction	5 (9.1)	1 (11.1)	0.847
Hypoxic encephalopathy	1 (1.8)	0	0.683
Transient ischemic attack	1 (1.8)	0	0.683
Acute renal failure	15 (27.3)	4 (44.4)	0.295
Bleeding	2 (3.6)	1 (11.1)	0.325
Sternal wound infection	2 (3.6)	0	0.561
Complete AV block s/p PPM	0	1 (11.1)	0.012
In-hospital mortality	6 (10.9)	1 (11.1)	0.985

AV = Atrioventricular; PPM = Permanent pacemaker; VRC = Vascular ring connector

DISCUSSION

AAAD is a life-threatening aortic emergency, with an incidence estimated to be 2.5–16 cases per 100,000 persons every year.[5,6] Autopsy studies have suggested that untreated AAAD can increase the mortality by 1%/h up to a cumulative 50% mortality within the first 48 h of diagnosis.[7] AAAD requires prompt surgical treatment, and expeditious surgery can reduce in-hospital mortality to 27%, compared with medically treated type A dissections (mortality 56%).[8] The primary principles of AAAD surgery are resection of the primary intimal tear (entry), replacement of the aortic wall, and correction/alleviation of complications and malperfusion syndromes. Because of tissue fragility, replacement of a segment of dissected aorta with a vascular prosthesis with sutures may result in lethal bleeding with conventional suture techniques because the fine threads may cut through the unhealthy aortic wall. For adequate hemostasis, prolonged CPB time may also be necessary and result in decreased platelet count and disturbed platelet function.[9] Coagulopathy may be further aggravated by the use of heparin and prolonged hypothermia. In addition, the dissection itself generates activation of inflammatory, coagulation, and fibrinolytic cascades. This leads to a profound consumption of coagulation factors, which leads to bleeding. Blood leakage from anastomoses and CPB-related coagulopathy are disasters for cardiovascular surgeons. Decreasing the perioperative bleeding and reducing the CPB-related organ dysfunction are crucial for the outcomes of patients undergoing an operation for AAAD.

Various techniques, including double-mattress sutures with Teflon felt, biological glue, and gelatin-resorcin-formalin glue, are reported to decrease bleeding in operation for AAAD.[10]

Regarding suture technique, to facilitate the anastomosis of fragile aorta and vascular graft, sutureless intraluminal grafts (SILGs) have been used for surgical repair of aortic dissection.[11] However, in addition to possible pressure gradient over the anastomosis site because of the suboptimal design that limited its internal diameter, the follow-up results were not satisfactory, with the risks of dehiscence, pseudoaneurysm, and hemolysis.[12-14] To overcome these drawbacks of early intraluminal graft, Dr. Wei re-designed the new VRC that is composed of biocompatible titanium alloy with two grooves on the outer surface and is made in various sizes (ranging from 12 mm to 30 mm in diameter) for individual need of different patients. The device is inserted into either one or both ends of the vascular prosthesis to form a single-ring or double-ring SILG. The braided tape can be tied around the overlapping region of the aorta and VRC, which provides a sutureless anastomosis.[3] Satisfactory early and mid-term results were also reported.[4] Based on our study, no significant difference of cardiac ischemic time and CPB time was observed between the VRC and suture groups. However, blood transfusion within 24 h, mediastinal drainage within 72 h, and time to extubation were significantly reduced in the VRC group. Moreover, 36.3% of patients in the VRC group did not require blood transfusion, compared to 22.2% in the suture group. In addition, in the VRC subgroup (one-VRC vs. two-VRC groups) analysis, significantly shorter cardiac ischemic time and CPB time were observed in the two-VRC group compared to the one-VRC group, which may contribute to the trend of shorter ICU and hospital stay in the two-VRC group. These results demonstrated the efficacy of VRC in operation for AAAD, and VRC is satisfactory and even better than conventional suture technique in certain aspects. Improved clinical outcomes were also shown using two-VRC method compared to one VRC group, which revealed the benefits of time-saving for the anastomosis.

Although an emergent operation for AAAD is a life-saving procedure, patients who survive after an emergent operation still have a risk of late aortic complication. Late aortic root events, such as aortic regurgitation, dilatation of the aortic root, and formation of pseudoaneurysm, have been reported to occur in 9%–27% of type A aortic dissection patients after the primary operation.[15-17] In our presented series, no reoperation was necessary in our VRC group till date. Nevertheless, VRC-related pseudoaneurysm of the descending aorta was described in a previously published study, where it was successfully treated with thoracic endovascular aortic repair (TEVAR).[18] With accumulating experience, hybrid operation including the use of VRC and TEVAR simultaneously may provide benefits for some selected patients. Besides, anticoagulation should be considered because of the inherent thrombogenicity from the intravascular alloy. Long-term surveillance for thrombosis events and ideal period and level for anticoagulation therapy should be verified in the future.

The limitations inherent to a retrospective analysis are present in this study. In addition to the cohort size being small, some covariates such as intraoperative and postoperative hemodynamic parameters and the extent of the dissection based on the surgeon's level of experience could not be included in the analysis. Nonetheless, our operative techniques and postoperative management remained quite similar during the time period of these two cohorts.

CONCLUSION

Our study showed that the use of VRC in emergent operation for patients with AAAD was associated with mortality, complications, and most clinical outcomes comparable to traditional suture technique. Decreased blood transfusion within 24 h and mediastinal drainage within 72 h in the VRC group may prevent patients from blood transfusion-related complications. In addition, the added benefit of avoiding blood transfusion cannot be overlooked. Moreover, the reduced cardiac ischemic time and CPB time in the two-VRC group may contribute to the trend of shortened ICU and hospital stay and improve the clinical outcomes. To our knowledge, our study is the first to demonstrate the clinical outcomes and benefits of VRC in AAAD. However, further randomized clinical trials on the benefit of VRC, ideal anticoagulation therapy, and long-term complications are warranted.

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Conflicts of interest

There are no conflicts of interest.

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