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Mid-term results of aortic root repair using the reimplantation technique: our single-center experience

Reimplantasyon tekniği kullanılarak yapılan aort kök tamirinin orta dönem sonuçları: Tek merkezli çalışma deneyimimiz

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ABSTRACT

Background: This study aims to report early and mid-term results of valve-sparing aortic root replacement using the reimplantation technique.

Methods: A total of 54 consecutive patients (44 males, 10 females; mean age 58±12.3 years; range 26 to 80 years) who underwent valve-sparing aortic root replacement using the David-V technique performed by a single surgeon at a single center between January 2008 and June 2015 were retrospectively analyzed.

Results: The in-hospital mortality rate was %1.9. The median follow-up was 57.5 (range, 29.5 to 77) months. Two patients developed severe aortic insufficiency during the first year following surgery and underwent aortic valve replacement. Estimated survival rates were 96.2±0.03%, 96.2±0.03% and 96.2±0.03% at one, five, and seven years, respectively. Moderate to severe aortic insufficiency-free survival rates were 96.2±0.03%, 96.2±0.03% and 96.2±0.03% at one, five, and seven years, respectively. Survival rates free from valve related re-operation at one, five, and seven years were 96.2±0.03%, 96.2±0.03% and 96.2±0.03% respectively.

Conclusion: Our early and mid-term results of the valve-sparing root reimplantation procedures for aortic root aneurysms are excellent.

Keywords: Aortic regurgitation; aortic root aneurysm; aortic root replacement; David`s reimplantation technique; Valve-sparing.

ÖZ

Amaç: Bu çalışmada reimplantasyon tekniği kullanılarak kapak koruyucu aort kök replasmanının erken ve orta dönem sonuçları bildirildi.

Çalışma planı: Ocak 2008 - Haziran 2015 tarihleri arasında, tek merkezde tek cerrah tarafından David-V tekniği kullanılarak kapak koruyucu aort kök replasmanı yapılan toplam ardışık 54 hasta (44 erkek, 10 kadın; ort. yaş 58±12.3 yıl; dağılım 26-80 yıl) retrospektif olarak incelendi.

Bulgular: Hastane içi mortalite oranı %1.9 idi. Medyan takip süresi 57.5 (dağılım 29.5-77) ay idi. Cerrahinin ilk yılında iki hastada şiddetli aort yetmezliği gelişti ve aort kapak replasmanı yapıldı. Bir, beş ve yedinci yılda tahmini sağkalım oranı sırasıyla %96.2±0.03, %96.2±0.03 ve %96.2±0.03 idi. Orta ila şiddetli aort yetmezliği olmaksızın sağkalım oranı bir, beş ve yedinci yılda sırasıyla %96.2±0.03, %96.2±0.03 ve %96.2±0.03 idi. Bir, beş ve yedinci yılda yeniden kapak ameliyatı olmaksızın sağkalım oranı sırasıyla %96.2±0.03, %96.2±0.03 ve %96.2±0.03 idi.

Sonuç: Kapak koruyucu aort kök reimplantasyon işlemlerimizin erken ve orta dönem sonuçları mükemmeldir.

Anahtar sözcükler: Aort yetmezliği; aort kök anevrizması; aort kök replasmanı; David reimplantasyon tekniği; kapak koruyucu.

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Replacing the aortic valve and root with a composite valve-graft, first described by Bentall and De Bono,[1] yields excellent mid-term and long-term outcomes for patients with aortic root pathology and is considered as the gold-standard for surgery in patients with a stenotic aortic valve and concomitant aortic root aneurysm.[1,2] In patients presenting with aortic root dilatation with or without concomitant aortic valve regurgitation, but morphologically intact aortic cusps, techniques for valve-sparing replacement of the aortic root have been developed to preserve the functionality and superior hemodynamics of the native aortic valve.[3,4] In addition, the potential complications related to the use of mechanical valves such as systemic thromboembolic complications, hemorrhage, and infective endocarditis can be avoided. Whereas homografts and bioprostheses do not require anticoagulation, they have limited durability and, thus, they are not ideal for young patients.[3,4]

The most widespread techniques for valve-sparing replacement of the aortic root are the remodeling of the aortic root described by Sarsam and Yacoub[5] and the reimplantation of the aortic valve described by David and Feindel.[6] The David's technique provides better stabilization of all components of the aortic root (aortic annulus, aortic sinuses, and sinotubular junction), thus, reimplantation of the aortic valve described by David has provided the best results for the long-term durability.[7,8]

In patients with a dilated aortic root, aortic valve preservation is technically challenging and controversy persists regarding the durability of the aortic root repair using the reimplantation technique and reproducibility of the procedure, although several authors have reported excellent durability of valve-sparing surgeries.[9-13] Therefore, in this study, we aimed to report early and mid-term results of valve-sparing aortic root replacement using the David's reimplantation technique in a single-center.

PATIENTS AND METHODS

We conducted a retrospective study which included 54 consecutive patients (44 males, 10 females; mean age 58±12.3 years; range 26 to 80 years) who underwent valve-sparing aortic root replacement using the David's reimplantation technique (David-V) performed by a single surgeon at a single center between January 2008 and June 2015. Preoperative and follow-up data were collected retrospectively. Preoperative data were gathered from the chart reviews. Follow-up data were obtained from the chart reviews or direct telephone interviews. The cut-off date for follow-up was 01.07.2015. The study protocol was approved by the Ankara Liv Hospital Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The functional status was determined according to the New York Heart Association (NYHA) classification. Operative mortality was defined as death within 30 days of surgery or in-hospital death. All patients underwent echocardiography during the follow-up period. Transthoracic echocardiogram was performed before discharging the patient from the hospital, at two months, and then every 6 to 12 months. The degree of preoperative and postoperative aortic insufficiency (AI) was confirmed by transthoracic or transesophageal echocardiography. It was graded as 0: absent; 1+: mild; 2+: moderate; 3+: moderate to severe, and 4+: severe. The ventricular function was graded using two-dimensional echocardiography and evaluated as normal (ejection fraction ≥50%), moderately impaired (ejection fraction 30-49%) or severely impaired (ejection fraction <30%). Computed tomography angiography was performed to all patients to assess the size of the aortic root, ascending aorta, and aortic arch. The diagnosis of Marfan syndrome (MFS) was based on recently revised Ghent criteria.[14]

Surgical techniques

All operations were performed by a single experienced surgeon. The setting of the cardiopulmonary bypass (CPB) and details of the techniques involved in cannulation of brachial artery were as described in our previous report.[15] A brief overview of our technique is as follows.

All procedures were performed with a median sternotomy. Cannulation of the right upper brachial artery was done before median sternotomy. Standard non-pulsatile CPB with a roller pump and a membrane oxygenator was used. The extracorporeal system was primed with the Ringer Lactate. Cardiopulmonary bypass was established between the right upper brachial artery and the right atrium using dual-stage venous cannulation. Venous drainage was provided using a single cannula, unless surgical maneuvers are required on the mitral or tricuspid valves. Cardiac arrest was established by cold crystalloid antegrade/retrograde cardioplegia. Cold blood cardioplegia was infused in an antegrade/retrograde fashion. Cardioplegia administration was repeated every 20 minutes. Moderate hypothermia (28 °C) was used in all patients.

Aortic root reconstruction was made by the David-V reimplantation technique. Details of the techniques involved in root reimplantation were as described in previous reports.[16] In brief, the aortic sinuses were excised and approximately 5 mm of aortic wall was left attached to the annulus. The Hegar dilator (Aesculap, Tuttlingen, Germany) was used to size the annulus. The diameter of the graft was determined by adding 10 mm to the Hegar dilator-sized annulus. Then, subannular horizontal mattress sutures were placed circumferentially below the aortic valve annulus from inside to out and across an appropriately sized Dacron graft. The graft is, then, lowered into its position below the annulus and the sutures are tied over an appropriately sized Hegar dilator placed across the aortic valve. After re-suspending each commissure at an appropriate height, the valve was attached to the wall of the Dacron graft using running polypropylene suture. Finally, coronary artery buttons were re-implanted into the graft in an anatomic fashion. A straight tubular graft was used in all patients.

All arch reconstructions (total or partial) and distal anastomoses were performed with an open aortic anastomosis technique. Antegrade cerebral perfusion was used in all cases.[15] As all patients in the study group had ascending aortic aneurysms extending to the brachiocephalic artery origin and application of the cross-clamp proximal to the innominate artery would influence the security of the distal anastomosis, an open distal anastomosis technique was the preferred method for the ascending aortic aneurysms.[15]

Statistical analysis

Statistical analysis was performed using the PASW for Windows version 17.0 (SPSS Inc., Chicago, IL, USA). All variables were analyzed using the visual (histograms, probability plots) and analytic methods (Kolmogorov-Smirnov test) to identify whether they are normally or abnormally distributed. Continuous variables were expressed in mean ± standard deviation (SD) for normally distributed variables and in median and interquartile range (IQR) for the non-normally distributed variables. Categorical variables were presented in numbers and percentages. Kaplan-Meier analysis was used for the evaluation of long-term survival and event-free survivals (freedom from greater than mild aortic regurgitation and reoperation). Values were expressed in mean and standard error. Risk factors for recurrent aortic insufficiency and reoperation were unable to be determined by low occurrence. A p value of <0.05 was considered statistically significant.

RESULTS

Preoperative characteristics of the patients are described in Table 1. All patients suffered from an ascending aortic aneurysm; 50 of them (92.5%) had aortic root aneurysm, while 41 (75.9%) had moderate or severe aortic regurgitation. Of the patients, 9.3% had none

Table 1. Preoperative data (n=54)

	n	%	Mean±SD
Mean age (years)			58±12.3
Body surface area (m^2)			1.8±0.2
Sex			
Male	44	81.5	
NYHA functional class			
Class I	26	48.1	
Class II	23	42.6	
Class III	5	9.3	
Class IV	0	0	
Associated diseases			
Diabetes mellitus	4	7.4	
Hypertension	32	59.3	
Hyperlipidemia	12	22.2	
COPD	13	24.1	
Thyroid disease	3	5.6	
Coronary artery disease	17	31.5	
Previous stroke	4	7.4	
Peripheral vascular disease	0	0	
Hemodialysis	0	0	
Pulmonary embolism	1	1.9	
Marfan syndrome	1	1.9	
Coarctation of the aorta	1	1.9	
Type A aortic dissection	1	1.9	
Root aneurysm	50	92.6	
Aortic root diameter (mm)			55.1±7
Preoperative aortic insufficiency			
None to trace	5	9.3	
Mild	8	14.8	
Moderate	16	29.6	
Severe	25	46.3	
Aortic valve pathology			
Bicuspid aortic valve	4	7.4	
Tricuspid aortic valve	50	92.6	
Ascending aorta aneurysm	54	100	
Left ventricular ejection fraction			
≥50	41	75.9	
30-50	13	24.1	
<30	0	0	
Preoperative coronary angiogram			
0 Vessel disease	38	70.4	
1 Vessel disease	9	16.7	
2 Vessel disease	5	9.3	
3 Vessel disease	2	3.7	
Arrhythmia (atrial fibrillation)	2	3.7	

SD: Standard deviation; COPD: Chronic obstructive pulmonary disease.

Table 2. Operative data (n=54)

	n	%	Mean±SD	Median	Interquartile range
Previous cardiac surgery	1	1.9			
Emergency operation	1	1.9			
Concomitant surgery	39	72.2			
Mitral valve repair	1	1.9			
Hemi-arch replacement	30	55.6			
Total arch replacement	2	3.7			
Elephant trunk	2	3.7			
Ascending-to-descending aortic bypass graft	1	1.9			
Coronary bypass surgery	16	29.6			
Cross clamp time, minutes, median				152	138-167
Cardiopulmonary bypass time				179	159.2-192.5
Circulatory arrest	41	75.9			
Circulatory arrest time			18.7±8.7		
Operation time				330	300-360
Postoperative inotrope requirement	13	24			
Intra-aortic balloon pump	2	3.7			
Re-exploration for bleeding	4	7.4			
In-hospital mortality	1	1.9			

SD: Standard deviation.

to trace and 14.8% had mild aortic insufficiency. In patients with none to trace or mild aortic insufficiency, indication for the David-V technique was aortic root aneurysm. One patient (1.9%) was diagnosed with MFS, one (1.9%) with type A aortic dissection, and four (7.4%) with a bicuspid aortic valve (BAV) (Table 1).

Operative profiles of the patients are depicted in Table 2. The median aortic cross-clamp and the total CPB times were 152 (138-167) min and 179 (159.2-192.5) min, respectively. Of the patients, 72.2% had simultaneous surgery (Table 2). There was no operative death.

The median length of stay in the ICU and hospital was 20 (range, 17 to 40) hours and five (range, 5 to 6.75) days, respectively. The in-hospital mortality rate was %1.9. A 74-year-old male patient with a previous history of CVD who underwent simultaneous hemiarch replacement and coronary artery bypass grafting (CABG) required re-exploration for refractory low cardiac output syndrome and malignant arrhythmias. Unfortunately, he died from refractory low cardiac output following the operation. The re-exploration rate for refractory low cardiac output syndrome was 1.9%. Four patients (7.4%) required re-exploration for bleeding. Postoperative inotropic support for ≥12 hours was required in 24% of patients. Two patients (3.8%) needed insertion of an intra-aortic balloon pump due to an unexplained refractory low cardiac output syndrome. One patient (1.9%) developed complete heart block which necessitated a permanent pacemaker placement before discharge. There was no perioperative myocardial infarction or infection. No cerebrovascular events were observed during the postoperative and follow-up period.

The clinical follow-up extended from 0 to 89 months. The median follow-up was 57.5 (range, 29.5 to 77) months. All patients completed at least one year follow-up. There were 46 patients followed beyond five years, but only 25 beyond seven years. During the follow-up, a 69-year-old female patient with a previous history of CVD and chronic obstructive pulmonary disease (COPD) who underwent simultaneous hemiarch replacement died due to pulmonary thromboembolism three months after the operation.

No patient had more than mild AI on echocardiogram prior to discharge. The postoperative repeated echocardiography showed none-to-trace AI in 37 patients (68.5%) and mild AI in 15 patients (27.8%). Two patients developed severe AI due to the cusp prolapse during the first year following surgery and underwent aortic valve replacement. There were no operative deaths among patients who needed re-do surgery. During the follow-up, no enlargement of the aortic annulus, sinuses of Valsalva or sinotubular junction were observed.

Estimated survival rates were 96.2±0.03%, 96.2±0.03% and 96.2±0.03% at one, five, and seven years, respectively. Postoperative survival rates are

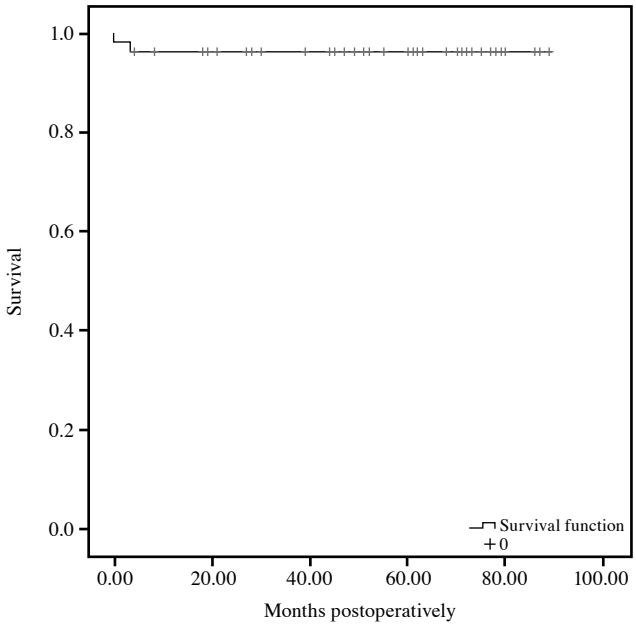

Figure 1. Survival after operation.

shown in Figure 1. Freedom rates from moderate to severe AI were 96.2±0.03%, 96.2±0.03% and 96.2±0.03% at one, five, and seven years, respectively. Freedom rates from valve-related reoperation at one, five, and seven years were 96.2±0.03%, 96.2±0.03% and 96.2±0.03%, respectively. Freedom rates from recurrent AI greater than mild and valve-related reoperation are shown in Figures 2 and 3, respectively.

DISCUSSION

The results of the present study demonstrated that valve-sparing aortic root procedure using the David-V technique could be performed at low risk with favorable early and mid-term survival and satisfactory freedom from reoperation and moderate-to-severe AI. Our mid-term outcomes with valve-sparing aortic root replacement are similar to those reported in the literature.[4,9,11]

Most series report in-hospital mortality between 0% and 6% among patients who underwent reimplantation procedures.[8] The largest series in the literature with long-term follow-up was reported by David et al.[9] in 2013 and included data of 296 patients (36% MFS and 11% BAV). David et al.[9] reported an early mortality rate of 1.3 % in their series. De Paulis et al.[17] reviewed a multicenter experience of the reimplantation procedure with the Valsalva graft in 278 patients (15% MFS; 5% acute aortic dissection and 11% BAV). They reported an early mortality of 1.8%. There was only one in-hospital death (1.9%) in the present series. A high-risk patient who underwent concomitant David-V procedure, hemiarch replacement and CABG, died from refractory low cardiac output following the operation. During the follow up, one patient died due to pulmonary thromboembolism three months after the operation. In the current series, despite the high-risk patient population (older age, higher prevalence of preexisting comorbidities, high concomitant CABG

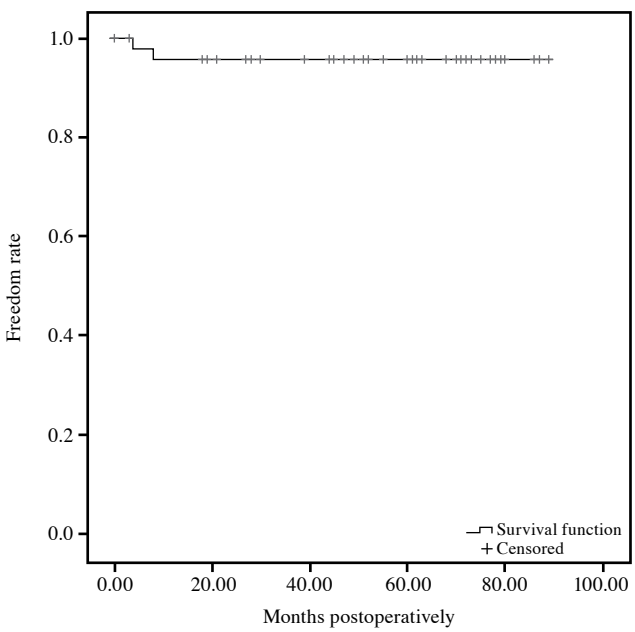

Figure 2. Freedom from recurrent aortic insufficiency greater than mild.

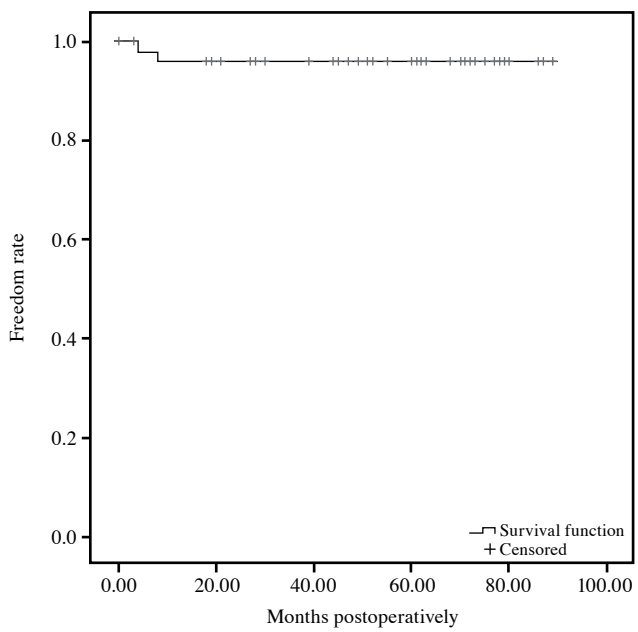

Figure 3. Freedom from aortic valve reoperation.

and aortic arch surgery rates) estimated survival was 96.3±0.03% at one-year during follow-up. Survival rate at one year was reported to be 97.6±2.6% by David et al.[9] and 97±1.5% by Forteza et al.[10] Overall survival was 96.2±0.03% and 96.2±0.03% at five, and seven years during follow-up. Five-year and 15-year survival rates were reported to be 95.1±3.5%, and 76.5±18% by David et al.[9] Miyahara et al.[11] reported that overall survival was 96.6±1.6% and 90.1±6.4% at five and 10 years in patients with expanded indications (24.6% connective tissue disorders; 19.1% BAV; 11.5% acute type A aortic dissection).

Currently, the main concern regarding aortic valve-sparing operations is long-term durability, measured as freedom from AI. There was no in-hospital repair failure in our series. During one-year follow-up, two repair failures occurred and had early reoperation. In David's series of 296 patients, the freedom from moderate or severe AI in all patients at one, five, 10, and 15 years was 99.6±0.8%, 98.3±3.5%, 92.9±6.5%, and 89.4±12%, respectively and the rate of freedom from aortic valve intervention at five, 10, and 15 years were 99.7±2.0%, 97.8±5.3%, and 97.8±5.3%, respectively.[9] In De Paulis' series of 278 patients (15% MFS; 5% acute aortic dissection and 11% BAV), the freedom from residual significant AI rate was 93.4% at five years and 88% at 10 years; and freedom from late aortic valve replacement was 92.6% at five years and 91% at 10 years.[17] In the current series, the rate of freedom from moderate to severe AI was 96.2±0.03% and 96.2±0.03% at five, and seven years, respectively. Freedom rates from valve-related reoperation at five and seven years were 96.2±0.03% and 96.2±0.03%, respectively.

The role of the valve-sparing aortic root replacement is unclear for patients with BAV, type A aortic dissection, and connective tissue disorders. Previous studies have shown favorable results for expanded indications including BAV,[18-20] connective tissue disorders,[21-24] and type A aortic dissection.[25] Of the patients, 1.9% had aortic dissection, 1.9% had MFS, and 7.4% had BAV in our series. However, the sample size was too small to draw a definite conclusion on the outcome in these patient subgroups. However, there were no failures among patients who had BAV, MFS or aortic dissection.

Altogether, an argument can be made that proceeding with valve-sparing aortic root replacement in patients requiring simultaneous procedures may increase morbidity and mortality rates, compared to the composite valve-graft replacement of the aortic root in patients requiring simultaneous procedures. Valve-sparing aortic root replacement increases the operative, bypass, and cross-clamp time, compared to the composite valve-graft replacement of the aortic root in patients requiring simultaneous procedures. Additionally, patients who require simultaneous procedures represent the high-risk group with multiple-morbidity. Several studies have reported increased morbidity and mortality rates after valve-sparing aortic root replacement procedures among patients requiring simultaneous surgery,[26] while some were unable to find a significant association.[27] The decision to proceed with composite valve-graft replacement of the aortic root or valve-sparing aortic root replacement was at the discretion of the attending surgeon in our series. An individualized technique was chosen according to each patient's clinical and anatomical characteristics. Although valve-sparing aortic root replacement increases the operative, bypass, and cross-clamp times, compared to the composite valve-graft replacement of the aortic root in patients requiring simultaneous procedures, we believe our favorable outcomes support our policy of proceeding with valve-sparing aortic root replacement in patients requiring simultaneous procedures. In our opinion, the decision should be made individually for each patient and experience of the surgical team with aortic valve repair. In addition, aortic valve-sparing procedures should be considered while proceeding with valve-sparing aortic root replacement in patients requiring simultaneous procedures. Ideally, simultaneous procedures should only be applied in an elective basis.

On the other hand, there are some limitations to this study. First, this is a single-center retrospective study. Second, our study is that we were unable to identify factors associated with an increased risk for repair failure due to relatively small sample size. Third, the number of patients in some subgroups (those with BAV, aortic dissection, connective tissue disorders) is too small to draw a definite conclusion on the outcome in these patient subgroups. Therefore, further large-scale studies with long-term follow-ups are needed to identify the risk factors for repair failure.

In conclusion, based on our experience, early and mid-term results of aortic root aneurysms with or without aortic insufficiency using the David V technique are excellent. This study provides further support to the growing body of literature advocating for valve-sparing root reimplantation procedures in selected patients presenting with aortic root aneurysm with or without aortic insufficiency. However, it should be kept in mind that valve-sparing aortic root

replacements are complex procedures which demand a high level of surgical skill and judgement.

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