Relationship of Surgeon Experience and Outcomes of Surgery for Degenerative Mitral Valve Disease

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December 11, 2020

Abstract

Objective: To assess the impact of surgeon experience on the outcomes of degenerative mitral valve disease. Methods: We reviewed all patients who had surgery for degenerative mitral valve disease between 2011-2016. Experienced surgeon was defined as performing ? 25 mitral valve operations/year. Patient characteristics and outcomes were compared. Multivariable analysis was performed to identify factors associated with MR recurrence. Survival analysis for mortality was done using Kaplan Meier curve and Cox proportional Hazard method. Results: There were 575 patients treated by 9 surgeons for severe mitral regurgitation caused by degenerative mitral valve disease between 2011-2016. Three experienced surgeons performed 77.2% of the operations. Patients treated by less experienced surgeons had worse comorbidity profile and were more likely to have an urgent or emergent operation (P=0.001). Experienced surgeons were more likely to attempt repair (P=0.024), to succeed in repair (94.7% vs 87%, P=0.001), had shorter cross-clamp times (P=0.001), and achieved higher repair rate (81.3% vs 69.7%, P=0.005). Experienced surgeons were more likely to use neochordae (P=0.001) and less likely to use chordae transfer (P=0.001). Surgeon experience was not associated with recurrence (moderate or higher MR) within the first two years after surgery but was an independent risk factor for mortality (HR= 2.64, P=0.002). Conclusions: Techniques of degenerative mitral valve surgery differ with surgeon experience, with higher rates of repair and better outcomes associated with more experienced surgeons.

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Word count: 3651

Graphical Abstract

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Keywords : Mitral valve surgery; Clinical outcomes; Degenerative mitral valve disease; Surgeon experience

Abbreviations and Acronyms

MR : Mitral regurgitation

ECHO: echocardiogram

CI: Confidence interval

NYHA: New York Heart Association

OR: Odds ratio; **HR:** Hazard Ratio

HTN: Hypertension; **BMI:** body mass index; **DM:**Diabetes mellitus; **CHF:** Congestive heart failure

A fib: Atrial fibrillation

MAC: mitral annular calcification

CABG: Coronary artery bypass grafting

NY: N ew York

PVD: peripheral vascular disease

CVD: cerebral-vascular disease;

EF: ejection fraction.

ALP: anterior leaflet prolapse, **PLP:** posterior leaflet prolapse, **BLP:** bi-leaflet prolapse.

CX: cross-clamp; **LV:** left ventricle.

Introduction

Mitral valve repair is recommended by the U.S. and European guidelines as the gold standard operation for degenerative mitral valve disease, because it preserves the patient's native valve with excellent long-term durability and avoids the risks associated with valve replacement, including endocarditis and the need for long- term anticoagulation[1-3]. Repair feasibility may be affected by factors including complexity of valve pathology, concomitant procedures, and the general condition of the patient. Various techniques have been described for mitral valve repair. These include triangular resection, quadrangular resection with annular plication or sliding annuloplasty, folding plasty and Goretex neochordae placement for posterior leaflet pathology. Anterior leaflet prolapse is usually repaired by either chordae replacement or chordae transfer. Complete ring or partial band techniques are considered standard components of annuloplasties as they stabilize the repair[4-6]. Surgeon volume is commonly used as a surrogate for surgeon experience and is associated with higher valve repair rates, freedom from reoperation, and 1-year survival[7]. This study explores the impact of surgeon experience and surgical techniques on the outcomes of mitral valve surgery for degenerative valve regurgitation.

Methods

Settings and Patient population

Institutional electronic medical records from a tertiary care center in the United States were queried for patients who had mitral valve surgery for mitral regurgitation (MR) caused degenerative mitral valve disease between January 2011 and December 2016. Patients with MR due to pathology other than degenerative (endocarditis, hypertrophic obstructive cardiomyopathy, ischemic, and functional MR) were excluded from the analysis. Patient demographics, baseline characteristics, and other risk factors were recorded. Operative reports were reviewed by a research resident (S.Y.) trained by the senior author (A.G.). Mortality data were retrieved from the hospital electronic record system on the date of censoring (02/22/2020). Of note: hospital mortality data is updated monthly from the Connecticut state vital statistics which captures subjects who died within the state. The Institutional Review Board at Yale University approved this study. IRB protocol ID: 2000020356, approval date: 2/13/2019. Need for written patient consent was waived by the IRB.

Definitions

Experienced surgeon was defined as a surgeon who performed an average of [?]25 mitral valve surgeries/year (all mitral valve pathologies) throughout the study period, surgeons with <25 were defined as less experienced[8]. Valve pathology was defined according to leaflet involvement (posterior leaflet, anterior leaflet or bi-leaflet prolapse). Residual MR was defined as mild MR or less on intraoperative transthoracic echocardiogram (ECHO) at end of operation. Repair complexity was defined by a technical score summing the number of techniques used in the repair: Simple repairs used only a single technique, moderate repairs used 2-4, and complex repairs used 5 or more[9]. Recurrent MR was defined as moderate or higher MR on any follow-up ECHO.

Outcomes

The primary outcome of the study was successful valve repair versus replacement. Secondary outcomes included recurrent MR, reoperation for recurrence, and mortality.

Statistical analysis

Differences in patient characteristics according to surgeon experience were compared with two-tailed t-tests for continuous variables and Fisher's exact tests for categorical variables. Multivariable logistic regression analysis was performed to identify independent risk factors for MR recurrence by 2-year follow-up. Survival analysis for mortality was performed with Kaplan-Meier curve and Cox proportional hazard model. To identify variables to be included in the model, we first compared patients who died to patients who were still alive on the day of censoring and variables with P values [?]0.02 were included in the model. These variables are patient's age at the time of surgery, surgeon experience, valve replacement vs repair, hypertension, dyslipidemia, diabetes mellitus (DM), atrial fibrillation, congestive heart failure (CHF), chronic lung disease, and urgent/emergent operation. P value of <0.05 and 95% confidence interval (CI) were used to define

statistically significant differences. Analyses were conducted using Microsoft Excel 2019 and Prism 8.2 (GraphPad Software, San Diego, CA), and SAS 9.4 (SAS Institute Inc, Cary, NC).

Results

Between 2011 and 2016, 576 patients underwent mitral valve surgery for severe MR due to degenerative valve disease. Majority or 77.2% of the operations (n= 444) were performed by 3 experienced surgeons, and 6 surgeons with less experience performed 22.8 % of the operations (n=132). No patient left the OR with an unsatisfactory repair (moderate or higher MR on post-pump ECHO). Patients operated on by less experienced surgeons were more likely to be non-Caucasian, to have higher body mass index, chronic lung disease, CHF, lower ejection fraction, and to be undergoing an urgent or emergent operation. Other characteristics, including age, sex, smoking status, other comorbidities including DM, hypertension, dyslipidemia, dialysis, peripheral vascular disease, cerebrovascular disease, and previous myocardial infarction, New York Heart Association (NYHA) class and atrial fibrillation were not different between the two groups (Table 1).

Procedural details by surgeon experience are presented in Table 2. Experienced surgeons were more likely to attempt repair (P=0.024) and more likely to succeed in repair (P=0.001). Experienced surgeons were more likely to attempt repair of both anterior leaflet prolapse and bi-leaflet prolapse (P=0.005). There was no difference in attempted repair of posterior leaflet prolapse (P=0.871). Fewer patients had residual MR in the experienced group (P=0.03). Experienced surgeons had shorter mean cross clamp times (P<0.001). Less experienced surgeons used the trans-septal approach more often (P<0.001) and were more likely to describe leaflet restriction (P<0.001). Valve pathology represented by leaflets affected, calcification, and annular dilatation were not statistically different between both groups.

The technical score (number of techniques used in the repair) was not different between both groups, but the techniques used differed according to surgeon experience. Experienced surgeons were more likely to use neochordae (P<0.001), and less experienced surgeons used chordae transfer more often (P<0.001). Rates for other techniques were not significantly different between the two groups. (Table 3).

Repair rate was higher in the experienced group (81.3% vs 69.7%, P=0.005), and rationale for valve replacement differed by surgeon experience (P=0.001). Extensive calcification was the primary reason for replacement in the experienced group, whereas failure of attempted repair was the most common in the less experienced group (Table 4).

The overall rate of recurrence was 13% (n=61) over the study period. Most (69%) recurrences happened in the first 2 years after surgery (Figure 1). On multivariable logistic regression analysis; in the first two post-operative years, surgeon experience was not a risk factor for recurrence. Annular calcification was the only independent factor for higher risk of recurrence (OR = 8.98 CI 3.19-25.28). Patient's age, male sex, DM, hypertension, urgent/emergent surgery and anterior/bi-leaflet prolapse were not independent risk factors for recurrence (Figure 2). Of the patients with recurrent MR, 23% (n=14) underwent mitral reoperation, and the other 77% (n=38) were either asymptomatic or high risk for reoperation. Reasons for recurrence according to surgeon description in the operative reports included dehisced ring in 35.7% (n=5), new lesions in 35.7% (n=5), endocarditis in 14.3% (n=2), and torn neochordae in 14.3% (n=2). Of the patients who underwent reoperation, re-repair was performed in 35.7% (n=5), all of which were performed by experienced surgeons, and the remainder underwent valve replacement.

The overall mortality (throughout 2011-2020) was 11.1% (n=64), with a rate of 8% (n=37) in the experienced group and 21% (n=27) in the less experienced group. By KM method, adjusted survival was higher in patients treated by more experienced surgeons (log rank P<0.0001) (Figure 3). 5-years survival in the patients operated on by experienced surgeons was 93.9% (n=417) and 80.2% (n=105) in the patients operated on by less experienced surgeons. Independent risk factors for mortality on Cox model were: less experienced surgeon (HR= 2.64, P=0.002), age (HR=1.03, P=0.012), valve replacement (HR=1.75, P=0.04), CHF (HR=2.01, P=0.029) and chronic lung disease (HR=2.25, P=0.005) . DM, dyslipidemia, HTN, Afib and urgent/emergent surgery were not independent factors for mortality (Table 5).

Discussion

Variations in mitral valve surgery outcomes by geographic area and institution has been emphasized in multiple reports[10-12]. In this analysis, the outcomes of mitral valve surgery within the same institution were different according to the experience of the operator surgeon. Experienced surgeons were more likely to attempt repair, used different operative techniques and had higher repair rates. While surgeon experience was not an independent risk factor for post-repair MR recurrence, it was an independent risk factor for mortality (HR=2.66) irrespective of valve repair/replacement and the pre-operative characteristics of the patients.

As in the New York state data, we identified higher rates of both CHF and urgent/emergent surgery with less experienced surgeons. This suggests a possible trend in referrals where higher risk patients tend to be operated on by less experienced surgeons, who may be less inclined to perform MV repair under unfavorable conditions[8].

Interestingly, the number of techniques used in the repair was not different between experienced and less experienced surgeons, but the management of the anterior leaflet using neochordae — a complex technique requiring a high level of experience — resulted in higher repair rates in the experienced group. Leaflet resection and annuloplasty rates were similar between both cohorts and also similar to the national average, but artificial neochordae rates differed. In the national study, 22.7% of mitral valve repairs had artificial cord implantation, compared to 41.5% of repairs with experienced surgeons and 18.7% with less experienced surgeons in this analysis[13].

This analysis also addresses the effects of calcification on the mitral valve surgery outcomes. Extensive calcification extending to the leaflets was the most common reason for replacement, and mitral annular calcification (MAC) was the only independent risk factor for MR recurrence. MAC was reported in ˜ 20% of patients undergoing mitral valve surgery[14] and was an independent risk factor for valve replacement[15]. The extent of leaflet prolapse was not a risk factor for recurrence in this cohort, as opposed to previous literature where anterior leaflet and bi-leaflet involvement were associated with increased risk of recurrence[16-18]. Of note, these studies included patients who had surgeries decades ago, when the techniques of anterior leaflet repair were not well-established and adopted.

The recurrence rate over the study period in this cohort was 13%, of which 65% happened in the first year, which matches the existing literature[16]. The most common causes for recurrence were ring dehiscence and new lesions, which, at 36% each, largely matches previous studies[19, 20]. Surgeon experience was not a risk factor for MR recurrence after repair in this cohort as opposed to previous reports. This could be explained by the fact that less experienced surgeons were more likely to repair posterior leaflet prolapse and replace anterior and bi-leaflet prolapses.

Finally, patients operated on by experienced surgeons had better adjusted survival. This finding can't be explained by the repair/replacement rate or the preoperative characteristics of the patients as it was shown to be an independent factor in the Cox hazard model. This was reported on a larger scale in the NY state data and requires further research[8].

Limitations

There are several important limitations to this study. It is a retrospective single institution study and the techniques used in the repair in this study are largely surgeon's preference which might be different from institution to another. Even though, mortality analysis was adjusted for comorbid conditions and acuity of the surgery, it is still possible that the results are affected by factors that were not accounted for in the analysis. Not all mitral valve repair techniques were included in this analysis due to rare use. The effect of concomitant surgery (CABG or other valve) and the type of mitral valve replacement (biologic vs mechanical) were not assessed in this analysis, because they are out of the scope of the study.

Conclusion

Within the same institution, there are differences in surgical outcomes for degenerative mitral valve disease. Experienced surgeons are more likely to attempt repair and to use techniques like chordal replacement to achieve higher repair rates, which are associated with improved long-term mortality.

Funding

This study was not funded.

Acknowledgements:

None

Legends

Figure 1. Time from operation to detection of recurrent MR.

Figure 2. Odds ratios for MR recurrence by 2-years post-operatively. MAC: mitral annular calcification

Figure 3. Kaplan-Meier curves for mortality stratified by surgeon experience.

Table 1. Patient demographics and characteristics. BMI, body mass index; DM, diabetes mellitus; PVD, peripheral vascular disease; CVD, cerebral-vascular disease; MI, myocardial infarction; CHF, congestive heart failure; NYHA, New York Heart Association; EF, ejection fraction.

Table 2. Procedural details as derived from operative reports by surgeon experience.

ALP: anterior leaflet prolapse, PLP: posterior leaflet prolapse, BLP: bi-leaflet prolapse.

Table 3. Specific repair techniques used in patient undergoing mitral valve repair.

Table 4. Reasons for valve replacement. CX, cross-clamp; LV, left ventricle.

Table 5. Cox hazard ratios of mortality.

Table 1. Patient demographics and characteristics.

	Experienced n=444 (77.2%)	**Less experienced** n=131 (22.8%)	**P**
Age (mean ± SD)	66.1 ± 13.3	66.5 ± 4.9	0.326
Male sex	270 (60.8)	73 (55.7)	0.312
Race, Asian	4 (0.9)	2 (1.5)	0.001
Race, black	12 (2.7)	10 (7.6)	
Race, Caucasian	416 (93.7)	111 (84)	
Race, native American	0	1 (0.8)	
Race, other	6 (1.3)	7 (5.3)	
BMI (mean ± SD)	26.3 ± 5	28.7 ± 1.9	0.023
DM	56 (12.6)	20 (15.3)	0.463
Dyslipidemia	247 (55.6)	71 (54.2)	0.842
Dialysis	2 (0.4)	2 (1.5)	0.225
Hypertension	292 (65.8)	92 (70.2)	0.399
Current smoker	19 (4.3)	3 (2.3)	0.437
Chronic lung disease	41 (9.2)	22 (16)	0.025
PVD	22 (4.9)	9 (6.9)	0.383
CVD	33 (7.4)	13 (9.9)	0.362
Previous MI	45 (10.1)	14 (10.7)	0.870
CHF	152 (34.2)	58 (44.3)	0.039
NYHA class I	17 (3.8)	5 (3.8)	0.397

	Experienced n=444 (77.2%)	**Less experienced** n=131 (22.8%)	**P**
NYHA class II	33 (7.4)	8 (6.1)	
NYHA class III	53 (11.9)	21 (16.1)	
NYHA class IV	47 (10.6)	24 (18.3)	
Atrial fibrillation	68 (15.3)	26 (19.8)	0.227
EF% (mean ± SD)	58.7 ± 10.2	54 ± 15.6	0.040
Prior sternotomy	9 (2)	5 (3.8)	0.328
Urgent/emergent status	75 (16.9)	39 (29.8)	0.002

BMI, body mass index; DM, diabetes mellitus; PVD, peripheral vascular disease; CVD, cerebral-vascular disease; MI, myocardial infarction; CHF, congestive heart failure; NYHA, New York Heart Association; EF, ejection fraction.

Table 2. Procedural details as derived from operative reports by surgeon experience.

	Experienced n=444 (77.2%)	**Less experienced** n=131 (22.8%)	**P**
Pathology details	**Pathology details**	**Pathology details**	**Pathology details**
Anterior leaflet prolapse	85 (19.1)	26 (19.8)	0.126
Posterior leaflet prolapse	219 (49.3)	76 (58)	
Bi-leaflet prolapse	133 (29.9)	28 (21.4)	
Annular calcification	67 (15)	13 (9.9)	0.152
Leaflet calcification	32 (7.2)	6 (4.6)	0.422
Annular dilatation	35 (7.9)	16 (21.2)	0.160
Broken/elongated chordae	214 (48.2)	66 (50.4)	0.691
Leaflet restriction	18 (4)	14 (10.7)	<0.001
Approach	**Approach**	**Approach**	**Approach**
Thoracotomy	103 (23.2)	33 (25.2)	0.641
Direct left atrial access	437 (98.4)	118 (90)	<0.001
Decalcification	18 (4.5)	5 (3.8)	>0.999
Operation outcome	**Operation outcome**	**Operation outcome**	**Operation outcome**
Cross-clamp time (mean ? SD, minutes)	93.4 ?31.3	150.5 ?20.5	<0.001
Repair attempted	378 (85.1)	100 (76.3)	0.024
Repair attempted for ALP/BLP	197 (90.37)	36 (70.37)	0.0005
Repair attempted for PLP	179 (79.91)	61 (79.22)	.8710
Successful repair	358 (94.7)	87 (87)	0.001
Residual MR after repair	3 (0.8)	4 (4.4)	0.033
Bypass re-run	20 (4.5)	5 (3.8)	>0.999

	Experienced n=444 (77.2%)	**Less experienced** n=131 (22.8%)	**P**
Repair after bypass rerun	11 (5.5)	1 ()	0.322
Overall repair rate	361 (81.3)	91 (69.7)	0.005

ALP: anterior leaflet prolapse, PLP: posterior leaflet prolapse, BLP: bi-leaflet prolapse.

Table 3. Specific repair techniques used in patient undergoing mitral valve repair.

	Experienced n=361 (79.87%)	**Less experience** n=91 (20.13%)	**P**
Annuloplasty	354 (98)	90 (98)	>0.999
Triangular resection	106 (29.4)	26 (28.6)	>0.999
Quadrangular resection	118 (32.7)	21 (23.1)	0.098
Neochordae	150 (41.5)	17 (18.7)	<0.001
Chordal transfer	4 (1.1)	11 (12.1)	<0.001
Cleft closure	53 (14.7)	15 (16.5)	0.627
Commisuroplasty	47 (13)	8 (8.8)	0.369
Alfieri stitch	26 (7.2)	10 (11)	0.277
Simple valve repair	22 (6.1)	10 (11)	0.246
Moderate valve repair	318 (88.1)	75 (82.4)	
Complex valve repair	21 (5.8)	6 (6.6)	

Table 4. Reasons for valve replacement.

	Experienced surgeon N=83 (%)	**Less experienced surgeon N=40 (%)**
Extensive calcification	39 (46.99)	7 (17.5)
Repair failure	15 (18)	9 (22.5)
Leaflet restriction	10 (12)	7 (17.5)
To minimize CX time	10 (12)	4 (10)
Difficult exposure	6 (7.2)	3 (7.5)
Redo sternotomy	1 (1.2)	0
Severe LV dilatation	1 (1.2)	0
Not reported	1 (1.2)	10 (25)

CX, cross-clamp; LV, left ventricle.

Table 5. Cox hazard ratios of mortality.

Parameter	**Hazard Ratio**	**95% CI**	**P**
Less experienced surgeon	2.7	1.6-4.36	0.0002
Age	1.03	1.007-1.056	0.0117
Valve replacement	1.75	1.02-2.98	0.0401

Parameter	Hazard Ratio	95% CI	P
Dyslipidemia	0.88	0.5-1.54	0.6588
Diabetes Mellitus	1.64	0.9-2.9	0.1089
Atrial fibrillation	1.28	0.73-2.24	0.3863
Congestive heart failure	2.01	1.07-3.76	0.0286
Chronic lung disease	2.26	1.27-4	0.0053
Hypertension	1.54	0.77-3.04	0.2171
Urgent/emergent operation	1.57	0.88-2.8	0.1291

Conflict of Interest: none declared

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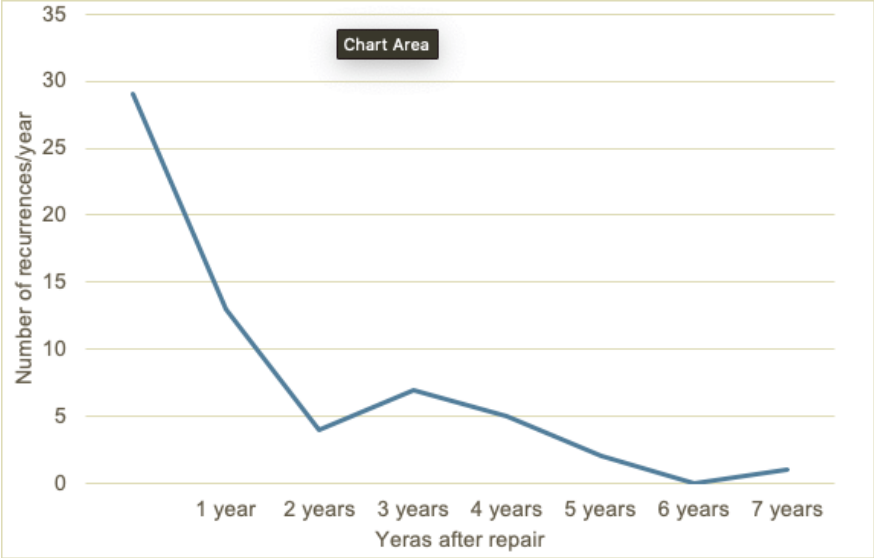

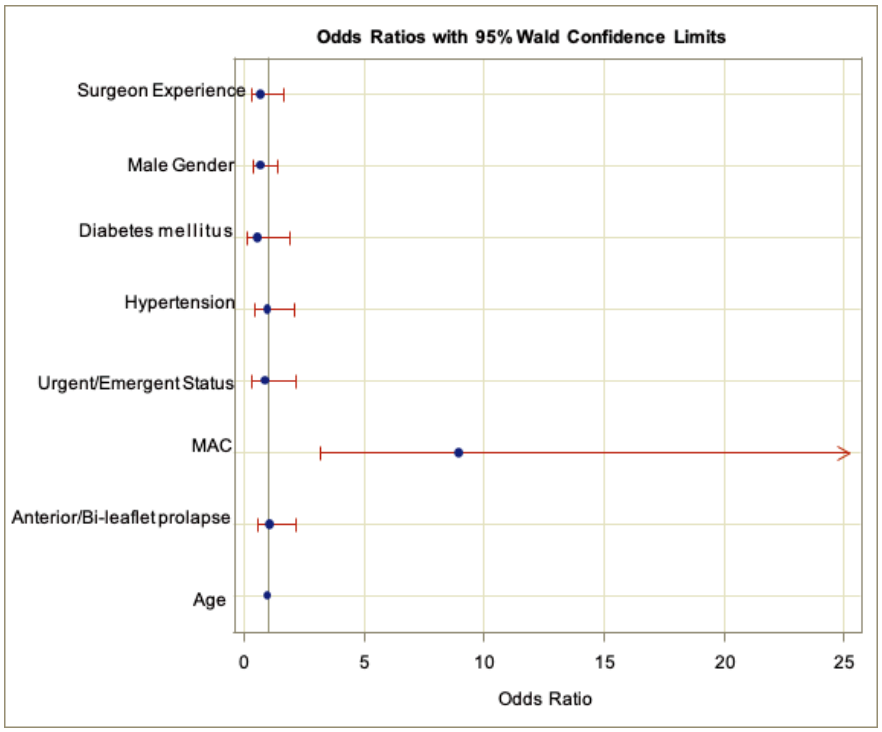

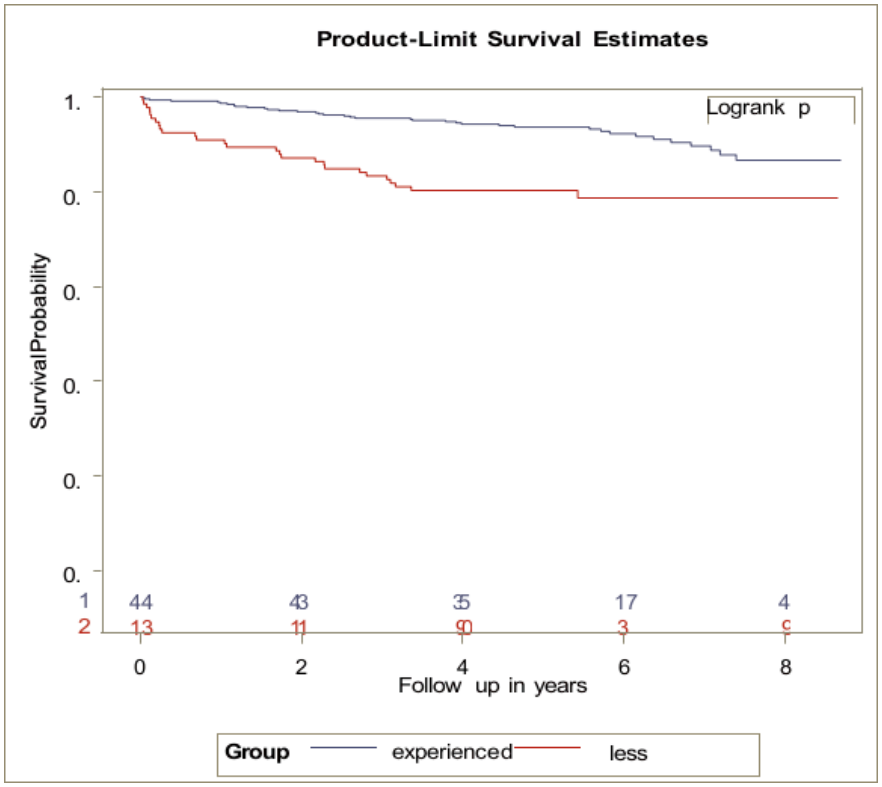

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