Risk Factors for Short-term Complications of Anterior Cruciate Ligament Reconstruction in the United States

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Background: Anterior cruciate ligament reconstruction (ACLR) is a commonly performed procedure that is highly successful in restoring knee stability and function. The incidence of early ACLR complications and the risk factors for these complications are not well defined.

Purpose: To determine the incidence of 30-day complications and patient and surgical risk factors for complications after ACLR.

Study Design: Cohort study; Level of evidence, 3.

Methods: Patients who underwent ACLR between 2005 and 2013 were identified in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database using Current Procedural Terminology billing codes. Postoperative complications in the 30-day period after surgery were identified. Potential patient and surgical risk factors for 30-day complications after ACLR were analyzed using univariate and multivariate analyses.

Results: A total of 4933 patients were identified. Major complications occurred in 27 patients (0.55%), and minor complications occurred in 43 patients (0.87%), with overall complications occurring in 66 patients (1.34%). The most common complications were symptomatic deep venous thrombosis requiring treatment (n = 27; 0.55%), return to the operating room (n = 18; 0.36%), superficial infections (n = 10; 0.20%), deep infections (n = 7; 0.14%), and pulmonary embolism (n = 6; 0.12%). A single mortality (0.02%) occurred. Multivariate analyses demonstrated that smoking, dyspnea, a history of chronic obstructive pulmonary disease, and recent weight loss were all risk factors for the development of overall complications, although in combination, these factors accounted for only 3% of the variance in the complication rate.

Conclusion: ACLR has a low incidence of complications (1.34%) in the early postoperative period, with the most common being symptomatic venous thromboembolic disease requiring treatment, return to the operating room, and infections. Because ACLR is an elective procedure, surgeons should use this information to counsel patients on risks and to guide their decision making about patient selection.

Keywords: anterior cruciate ligament reconstruction; anterior cruciate ligament tear; complication; National Surgical Quality Improvement Program; deep venous thrombosis

Anterior cruciate ligament (ACL) tears are common injuries encountered by the orthopaedic surgeon,[31,38] with ACL reconstruction (ACLR) considered the gold-standard treatment for active patients to restore knee stability and improve functional outcomes.[3,4] At over 10-year follow-up, ACLR reduces the rate of subsequent meniscal injuries, reduces the rate of further surgery, and improves activity levels compared with nonoperative treatment.[7] The incidence of ACLR is on the rise in the United States, increasing from 87,000 in 1994 to 130,000 in 2006.[27] ACL deficiency is thought to lead to knee instability, resulting in secondary meniscal and cartilage damage and potentially to accelerated degenerative changes.[7,25] Both patient and surgical factors are thought to influence ACLR functional outcomes and the rate of subsequent surgery, including the use of allografts, lateral meniscus status, body mass index (BMI), younger age, and smoking.[13,18,36]

ACLR is generally considered to be a safe procedure and is performed predominantly on an outpatient basis in the United States.[1,20,27] Although the literature addresses graft failure,[18,23,40] there is relatively little information available defining the rate of ACLR complications in the early perioperative period, such as deep venous thrombosis (DVT), pulmonary embolism (PE), infections, hospital readmission, reoperation, and mortality. Studies of ACLR perioperative complications have predominantly been small single-center series addressing DVT and infections, with limited information on patient risk factors and less frequent complications such as PE.[6,11,21,22,33,37,41] Only a few larger database studies of perioperative complications after ACLR have been reported in New York State and several European countries.[14,20,24,26]

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Knowledge of ACLR perioperative complication rates is important to allow surgeons to provide an accurate preoperative depiction of the risks and benefits of the procedure and potentially to identify patient and surgical risk factors that could be modified to prevent perioperative complications. The aim of this study was to determine the incidence of 30-day complications after ACLR and to identify patient and surgical risk factors for complications after ACLR using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. The NSQIP database has recently been applied to study complications in a variety of orthopaedic procedures,[2,16,17,29,30,34,35,39] but none has analyzed ACLR complications.

METHODS

Data Source

The ACS NSQIP database was chosen for this study because it provides high-quality, prospectively collected data on patients undergoing surgery at over 400 hospitals around the United States. The database does not include independent surgery centers. Surgical clinical reviewers prospectively follow the patients' medical charts, collecting demographics, comorbidities, intraoperative variables, and 30-day postoperative major and minor complications based on specified criteria. Hospitals with an interobserver disagreement rate between surgical clinical reviewers of >5% or a 30-day follow-up rate of <80% are excluded from the database to ensure high-quality data. As a result, the NSQIP is a high-quality, accurate database source for studying perioperative complications[9,12,19] and is well established for studying complications of orthopaedic procedures.[2,16,17,29,30,34,35,39] This database is well suited to our research purpose because the large sample size of the database affords us the ability to document rates of and risk factors for relatively rare perioperative complications after ACLR.

Patient Selection

We surveyed the database, including cases with the Current Procedural Terminology (CPT) code 29888 (cruciate ligament reconstruction) and excluding cases with the International Classification of Diseases, 9th edition (ICD-9) code 717.83 (posterior cruciate ligament disruption) to identify all isolated, elective ACLRs within the database between January 1, 2005 and December 31, 2013. Associated injuries and concomitant procedures at the time of ACLR are shown in Appendix Tables A1 and A2 (available online at http://ajsm.sagepub.com/supplemental) based on CPT and ICD-9 coding. Emergency cases and infections were excluded. Patients undergoing surgery for an acute traumatic injury for which they were admitted to the emergency department are not included in the database.

Data Collection

Complications were divided into major and minor categories in the same way as in prior literature.[30] Complications considered major and minor can be found in Table 1. An overall complication rate including both major and minor complications was also included. Mortality was counted as a major complication. Patient characteristics and surgical characteristics are rigorously defined by the ACS and are included in the NSQIP database. Continuous variables were categorized, and several categorical variables were recategorized as follows: age (<20, 20-29, 30-39, 40-50, or >50 years), anesthesia (general, regional, or monitored anesthesia care), surgical resident involvement (yes/no), diabetes (yes/no), functional status (independent or dependent), BMI (<18.5, 18.5-24, 25-30, or >30 kg/m^2), and operative time (<90 or >90 minutes). The Charlson Comorbidity Index was calculated from the medical history provided by the database as previously described.[5,8] The Charlson Comorbidity Index is a measure of medical comorbidities that assigns a score designed to predict 10-year mortality based on 22 comorbid conditions (Appendix Table A3, available online).[5,8]

Statistical Analysis

Three separate analyses were conducted: one for minor complications, one for major complications, and one for all complications. Both univariate and multivariate analyses were conducted. Univariate analyses functioned to identify variables for inclusion in the multivariate analyses. Table 2 lists the variables included in the univariate analyses. Several preoperative variables are available in the database but were not included in these analyses as none of the included patients had a history of pneumonia, ascites, esophageal varicosities, myocardial infarction, central nervous system tumors, quadriplegia, disseminated cancer, chemotherapy, radiation treatment, blood transfusion within 30 days before surgery, functional dependence, or wound infections. Chi-square and Fisher exact tests were used as appropriate. Multivariate logistic regression analyses were then conducted. To be inclusive, any variable with a P value of <.2 on any of the 3 univariate analyses was included in each of the 3 multivariate analyses;

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TABLE 1
Complications Experienced by 4933 Patients Who Underwent ACLR Within the NSQIP Database[a]

Complication	n (%)
Major	
Sepsis	0
Septic shock	0
Deep surgical infection	7 (0.14)
Dehiscence	2 (0.04)
Pulmonary embolism	6 (0.12)
Ventilator for >48 hours	0
Unplanned intubation	0
Acute renal failure	0
Cardiac arrest	0
Myocardial infarction	0
Cerebrovascular accident	0
Coma	0
Graft failure	1 (0.02)
Return to the operating room	18 (0.36)
Patients with major complications[b]	27 (0.55)
Minor	
Superficial infection	10 (0.20)
Pneumonia	1 (0.02)
Urinary tract infection	3 (0.06)
Deep venous thrombosis	27 (0.55)
Transfusion	2 (0.04)
Peripheral nerve injury	0
Renal insufficiency	0
Patients with minor complications[b]	43 (0.87)
Mortality	1 (0.02)
Overall complications	66 (1.34)

[a]ACLR, anterior cruciate ligament reconstruction; NSQIP, National Surgical Quality Improvement Program.
[b]Some patients experienced multiple complications.

otherwise, only those results with a P value of $<.05$ were considered significant. For multivariate analyses, 1.9% of cases were excluded because of missing BMI data.

RESULTS

Complications

A total of 4933 patients who underwent ACLR were identified between 2005 and 2013 in the NSQIP database. The number, percentage, and categorization of complications are shown in Table 1. Major complications occurred in 27 patients (0.55%), and minor complications occurred in 43 patients (0.87%), with overall complications occurring in 66 patients (1.34%). The most common complications were symptomatic DVT requiring treatment (n = 27; 0.55%), return to the operating room (n = 18; 0.36%), superficial infections (n = 10; 0.20%), deep infections (n = 7; 0.14%), and PE (n = 6; 0.12%) (Table 1). A single mortality (0.02%) occurred; the cause of this death was not available in the database. There was no change in the incidence of complications over time from 2005 to 2013 (P = .30 [major complications], .58 [minor complications], and .73 [overall complications]).

Univariate Analyses

Univariate analyses of risk factors for minor, major, and overall complications are shown in Table 2. Patient risk factors significantly associated with minor complications on univariate analyses were dyspnea (P = .041), history of chronic obstructive pulmonary disease (COPD) (P = .008), and unintentional weight loss over 10% of the body weight in the 6 months before surgery (P = .043). The only patient risk factor significantly associated with major complications on univariate analyses was the Charlson Comorbidity Index (P = .005). Patient risk factors significantly associated with overall complications on univariate analyses were smoking (P = .023), dyspnea (P = .013), and history of COPD (P = .019).

Multivariate Analyses

Independent risk factors identified by multivariate logistic regression analyses for minor, major, and overall complications are shown in Table 3. For minor complications, independent risk factors were history of COPD ($P < .001$; odds ratio [OR], 22.3 [95% CI, 4.7-105.3]), recent weight loss (P = .002; OR, 38.3 [95% CI, 3.9-372.0]), and smoking (P = .042; OR, 3.5 [95% CI, 1.1-11.5]). For major complications, there were no significant risk factors on multivariate analyses. For overall complications, independent risk factors were history of COPD (P = .016; OR, 8.0 [95% CI, 1.5-43.7]), dyspnea (P = .018; OR, 5.1 [95% CI, 1.3-19.3), smoking (P = .018; OR, 3.1 [95% CI, 1.2-7.8]), and recent weight loss (P = .006; OR, 24.3 [95% CI, 2.6-231.8]). In combination, these factors accounted for only 3% of the variance in the overall complication rate. This suggests that factors not measured within the NSQIP database, such as heterogeneity in the surgical technique, variations between facilities, and unmeasured patient factors (ie, undiagnosed coagulopathy), explain almost all of the variance in short-term complications after ACLR. Of included patients, 16 patients had COPD (0.32%), 37 had dyspnea (0.75%), and 4 had both COPD and dyspnea (0.08%).

DISCUSSION

This study used the large, prospectively collected, high-quality NSQIP database to determine the incidence of 30-day complications and patient and surgical risk factors for complications after ACLR. We found that the overall rate of complications after ACLR was 1.34%. Multivariate analyses demonstrated that smoking, dyspnea, a history of COPD, and recent weight loss were independent risk factors for any complication after ACLR.

The literature contains only a few database studies of ACLR complications in the early postoperative period, addressing New York State and several European countries.[14,20,24,26] We are unaware of a study that addressed ACLR complications for the United States. Jameson et al[20] analyzed 30- to 90-day complications after ACLR in England's National Health Service, finding a 0.3% DVT rate, a 0.18% PE rate, a 1.36% readmission rate,

TABLE 2
Results of Univariate Analyses[a]

Variable	Minor Complications			Major Complications			Overall Complications		
	With (n = 43)[b]	Without (n = 4890)	*P* Value	With (n = 27)[b]	Without (n = 4906)	*P* Value	With (n = 66)	Without (n = 4867)	*P* Value
Female sex	25.6	37.6	.106	33.3	37.5	.842	28.8	37.6	.143
Anesthetic type			.738			.698			.870
General	97.7	95.2		92.6	95.3		95.5	95.3	
Regional	2.3	4.4		7.4	4.3		4.5	4.3	
MAC	0	0.4		0	0.4		0	0.4	
Resident involved	26.1	31.8	.657	42.9	31.7	.394	33.3	31.7	.837
Smoking	7.0	18.1	.059	14.8	18.0	.806	7.6	18.1	**.023**
EtOH: >2 drinks/day	0	1.1	.600	0	1.1	>.999	0	1.1	>.999
Dyspnea	4.7	0.7	**.041**	96.3	99.3	.184	4.5	0.7	**.013**
History of COPD	4.7	0.3	**.008**	0	0.3	>.999	3.0	0.3	**.019**
History of CHF	0	0	>.999	0	0	>.999	0	0	>.999
Prior PCI	0	0.5	>.999	7.1	0.5	.073	2.7	0.5	.183
Prior PCS	0	0.3	>.999	0	0.3	>.999	0	0.3	>.999
History of angina	0	0.3	>.999	0	0.3	>.999	0	0.3	>.999
Dialysis	0	0	>.999	0	0	>.999	0	0.1	>.999
Hemiplegia	0	0.2	>.999	0	0.2	>.999	0	0.2	>.999
History of TIA	0	0.2	>.999	0	0.2	>.999	0	0.2	>.999
History of stroke	0	0	>.999	0	0	>.999	0	0	>.999
Paraplegia	0	0.1	>.999	0	0.1	>.999	0	0.1	>.999
History of steroid use	0	0.4	>.999	0	0.4	>.999	0	0.5	>.999
Recent weight loss	2.3	0.1	**.043**	0	0.1	>.999	1.5	0.1	.065
Bleeding disorder	0	0.2	>.999	0	0.2	>.999	0	0.2	>.999
Prior sepsis	0	0.1	.903	0	0.1	.938	0	0.1	>.999
Current pregnancy	0	0	.915	0	0	>.999	0	0.1	>.999
Surgery within 30 days preoperatively	0	0.3	>.999	0	0.3	>.999	0	0.3	>.999
Diabetes	0	1.9	>.999	3.7	1.8	.396	1.5	1.8	>.999
Age group, y			.113			.219			.341
<20	2.3	9.5		11.1	9.5		6.1	9.5	
20-29	44.2	35.8		25.9	35.9		39.4	35.8	
30-39	14.0	26.2		22.2	26.2		18.2	26.2	
40-50	27.9	19.8		37.0	19.8		27.3	19.8	
>50	11.6	8.6		3.7	8.7		9.1	8.6	
Race			.917			.677			.709
Native American	0	1.1		0	1.1		0	1.1	
Asian	5.9	8.0		4.2	8.0		5.5	8.0	
Black	11.8	8.8		12.5	8.8		12.7	8.8	
Hispanic	17.6	16.3		8.3	16.3		14.5	16.3	
White	64.7	65.9		75.0	65.8		67.3	65.8	
ASA classification			.907			.998			.960
I	48.8	53.7		51.9	53.7		51.5	53.7	
II	44.2	41.9		44.4	41.9		42.4	41.9	
III	7.0	4.3		3.7	4.3		6.1	4.3	
IV	0	0		0	0		0	0	
Charlson Comorbidity Index			.772			**.005**			.236
0	95.3	97.5		96.3	97.5		95.5	97.5	
1	4.7	2.2		0	2.2		3.0	2.2	
2	0	0.3		3.7	0.2		1.5	0.2	
3	0	0.1		0	0.1		0	0.1	
BMI[c]			.815			.078			.190
Underweight	0	0.4		0	0.4		0	0.4	
Normal	32.6	34.0		11.1	34.1		24.2	34.1	
Overweight	44.2	38.0		55.6	37.9		50.0	37.8	
Obese	23.3	27.6		33.3	27.6		25.8	27.6	
Operative time >90 minutes	62.8	51.1	.128	63.0	51.2	.222	62.1	51.1	.075

[a]Values are shown as the percentage of patients. Not all patients had data points available for all variables, and the percentage of the total available patients with data for a given risk factor was calculated. Bolded *P* values indicate statistically significant differences between groups ($P < .05$). ASA, American Society of Anesthesiologists; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; EtOH, ethanol; MAC, monitored anesthesia care; PCI, percutaneous coronary intervention; PCS, prior cardiac surgery; TIA, transient ischemic attack.

[b]Some patients experienced multiple complications.

[c]Underweight, <18.5 kg/m^2; normal, 18.5-24 kg/m^2; overweight, 25-30 kg/m^2; obese, >30 kg/m^2.

TABLE 3
Independent Risk Factors for ACLR Complications Identified by Multivariate Logistic Regression Analyses[a]

Variable	Variance in Complication Rate (R^2 Change)	Odds Ratio (95% CI)	*P* Value
Minor complications			
History of COPD	0.015	22.3 (4.7-105.3)	<.001
Recent weight loss	0.010	38.3 (3.9-372.0)	.002
Smoking	0.014	3.5 (1.1-11.5)	.042
Any complication			
History of COPD	0.009	8.0 (1.5-43.7)	.016
Recent weight loss	0.006	24.3 (2.6-231.8)	.006
Smoking	0.011	3.1 (1.2-7.8)	.018
Dyspnea	0.006	5.1 (1.3-19.3)	.018

[a]For major complications, there were no significant risk factors on multivariate analysis. ACLR, anterior cruciate ligament reconstruction; COPD, chronic obstructive pulmonary disease.

and a 0.25% rate of return to the operating room for septic arthritis. Lyman et al[26] analyzed 70,547 ACLRs in New York State and found a 90-day readmission rate of 2.3% after ACLR, higher among patients older than 40 years, those with pre-existing comorbidities, male patients, and low-volume surgeons. Several European countries have reported complications based on national ACLR registries: Norway in 2004, Sweden in 2005, and Denmark in 2005.[15] Norway had a 5% postoperative complication rate at 2-year follow-up, most often caused by graft failure; Denmark had a perioperative complication rate of 4.3%, although the nature of these complications or possible risk factors for complications were not specified in detail.[14,24] The Arthroscopy Association of North America members were surveyed in 1986 regarding complications, and an overall complication rate for all arthroscopic surgeries of 0.56% and a rate of 1.8% for ACLR were found.[10] Finally, Salzler et al[32] obtained data from the American Board of Orthopaedic Surgery database for examinees from 2003 to 2009 for all knee arthroscopic procedures including ACLR. They found an overall complication rate for knee arthroscopic procedures of 4.7%, with a rate of 9.0% for ACLR (although a breakdown of the complications after ACLR was not available). Our data report a similar complication breakdown to that in the available literature, with symptomatic venous thromboembolic disease requiring treatment (DVT and PE), reoperation, and infections being the most common perioperative ACLR complications. Our lower overall complication rate (1.34%) compared with that in the available literature may reflect the 30-day time frame of the NSQIP database, which is shorter than others included in the literature.

Two studies have used the NSQIP database to address complications of knee arthroscopic surgery and arthroscopic meniscectomy in the United States.[2,30] Martin et al[30] analyzed 12,271 knee arthroscopic procedures from 2005 to 2010, finding a 1.6% complication rate, most commonly DVT, superficial and deep infections, and return to the operating room. This study identified black race, prior operation within 30 days, operative time over 1.5 hours, and age of 40 to 65 years as independent risk factors for any complication on multivariate regression. Although this study included ACLR, the results were not stratified by procedure, in contrast to our study that looked exclusively at ACLR complications over a wider time range. Interestingly, our study found a lower overall complication rate than that by Martin et al,[30] which could be related to younger, healthier patients undergoing ACLR as opposed to knee arthroscopic procedures in general. Basques et al[2] analyzed 17,774 arthroscopic meniscectomies from 2005 to 2012, finding a 1.17% rate of any complication, with an American Society of Anesthesiologists classification of at least III, diabetes, smoking, and pulmonary disease being risk factors for complications. This study excluded patients undergoing ACLR or other major concomitant procedures and so is not directly comparable with our data and research purpose. We found a slightly higher complication rate of 1.34% after ACLR compared with 1.17% after meniscectomy for Basques et al.[2] Our risk factors for ACLR complications identified by multivariate regression had some similar factors as the prior studies on knee arthroscopic surgery and meniscectomy (including smoking and pulmonary disease) but also some factors not identified in the prior studies (including recent weight loss). The fact that NSQIP studies have identified some common risk factors for ACLR complications and other procedure complications suggests that surgeons should consider screening for these factors when considering elective surgery.

We found that the most common complication in the 30 days after ACLR is symptomatic DVT requiring treatment (0.55%) and that PE also occurs (0.12%). PE after ACLR was first reported in 2007 as a case report,[21] and the DVT rate after ACLR has been considered low enough (1/67 patients based on postoperative ultrasound screening) that routine prophylaxis was recommended only for those over 40 years old or with other risk factors.[11] A randomized trial, however, showed that a 20-day course of enoxaparin for DVT prophylaxis significantly reduced the rate of DVT after ACLR and that patients over 30 years old or with preoperative immobilization were at an increased risk of DVT.[28] There is wide variation between countries in the rates of the use of prophylactic anticoagulation after ACLR, from 17% in Denmark to 78% in Norway.[15] We found that symptomatic DVT requiring treatment was among the most common complications of ACLR, suggesting that future studies

are needed to further define indications for DVT prophylaxis after ACLR.

Strengths of our study include the use of the NSQIP database to provide high-quality data on ACLR in a variety of hospitals around the United States, with preoperative, intraoperative, and 30-day postoperative data.[9,12,19] This database is a well-established resource for studying complications of orthopaedic procedures.[2,16,17,29,30,34,35,39] The use of this database allowed us to determine the incidence of and patient and surgical risk factors for complications of ACLR. Another strength is that our study specifically addressed a large number of ACLR procedures rather than a heterogeneous set of orthopaedic procedures as some prior studies have done. We used robust statistical methodology including multivariate logistic regression to determine the independent risk factors for complications after ACLR, which controls for other patient and surgical factors.

Our study has several limitations, predominantly related to the NSQIP database's inherent limitations. The data are limited by the time frame of the database, which addresses only the 30-day postoperative period. Complications such as DVT, PE, and infections might occur after this 30-day period and would not be captured by our analysis. Also, the most common reasons for return to the operating room were not available in the database. Moreover, it is not possible from the data to determine if complications (particularly highly uncommon ones such as the 1 mortality and 2 postoperative transfusions) were related to the ACLR procedure. Despite the large number of centers included in the NSQIP database, procedures performed in independent surgery centers are not included in the database, so our results may not be representative of complication rates for ACLR performed in surgery centers. The patients in the NSQIP database could potentially have an older age distribution and more comorbidities than patients from surgery centers. In addition, orthopaedic-specific data of interest are not available in the database, including ACLR graft choice, use of DVT prophylaxis, postoperative weightbearing status, patient-reported outcome scores and pain scores, preoperative and postoperative range of motion and physical examination findings, and outcomes specific to ACLR such as recurrent or persistent instability and graft failure. Large prospective cohort or randomized controlled studies with a longer follow-up such as the Multicenter Orthopaedic Outcomes Network studies are needed to address outcomes such as graft failure after ACLR.[13,18,36] Instead, the use of the NSQIP database allowed us to determine the incidence of and risk factors for uncommon but serious complications in the perioperative period after ACLR, which is not well studied in the literature to date. In addition, our study did not allow us to determine the surgeon volume of ACLR or surgeon sports fellowship training status because of NSQIP data limitations designed to protect hospital, surgeon, and patient confidentiality. It is possible that the complication rate could depend on surgeon or hospital ACLR experience and volume, which we were unable to analyze. Next, our study is limited by the accuracy and completeness of the data in the NSQIP database. Patients with incomplete data had to be excluded, which could introduce bias. Overall, the NSQIP data have been shown to be a high-quality, accurate database source to study perioperative complications.[9,12,19] Finally, with large database studies, there is the potential for substantial statistical power to identify statistically significant findings that have little clinical importance. To address this, we also reported ORs to show the effect size of the risk factors identified in our multivariate regression.

CONCLUSION

ACLR has a low incidence of complications (1.34%) in the early postoperative period, with the most common being symptomatic venous thromboembolic disease requiring treatment, return to the operating room, and infections. Because ACLR is an elective procedure, surgeons should use this information to counsel patients on risks and to guide their decision making about patient selection.

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