

Application and validation of a surgical risk calculator in a liver surgery cohort of patients in Veracruz, Mexico

Aplicación de una calculadora de riesgo quirúrgico en una cohorte de pacientes de cirugía hepática en Veracruz, México

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Abstract

Objective: Multiple models have tried to predict the morbidity and mortality of liver resections (HR). This study aims to determine the efficacy and validity of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) surgical risk calculator in a cohort of patients undergoing HR in Veracruz, Mexico. **Material and methods:** Retrospective analysis of patients undergoing HR between 2005 and 2019. To estimate the performance of the calculator, the observed results were compared with the average risk predicted by the calculator, using ROC curve, Brier score and Z test. **Results:** 67 patients were evaluated, mean age 51.9 years of age, 50.7% female. The majority of resections (56.7%) were for malignancy and 62.1% were partial hepatectomies (up to 3 liver segments). The morbidity was 25.4% and the mortality 4.5%. There was a good prediction in the complications (serious complication: $C = 0.725$ statistic, Brier score 0.26, $p = 0.006$ and any statistical complication $C = 0.731$, Brier score 0.33, $p = 0.005$) and mortality ($C = 0.922$ statistic, Brier score 0.005, $p = 0.014$). **Conclusions:** The application of the ACS-NSQIP calculator in patients undergoing HR has good discrimination power and good predictive ability. Prediction of postoperative risks achieves a preoperative planning of the appropriate procedure.

Keywords: Hepatectomy. Risk calculator. Morbidity. Mortality. ACS-NSQIP.

Resumen

Objetivo: Múltiples modelos han intentado predecir la morbilidad y mortalidad de las resecciones hepáticas (RH). Este estudio tiene por objetivo determinar la eficacia y validez de la calculadora de riesgo quirúrgico del American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) en una cohorte de pacientes sometidos a RH en Veracruz, México. **Material y métodos:** Análisis retrospectivo de pacientes sometidos a RH entre 2005 y 2019. Se compararon los resultados observados con la media del riesgo previsto por la calculadora, mediante Curva ROC, score de Brier y prueba Z. **Resultados:** Se evaluaron 67 pacientes, con 51.9 años de edad media, un 50.7% de sexo femenino. La mayoría de las resecciones (56.7%) fueron por patología maligna y el 62.1% fueron hepatectomías parciales. La morbilidad fue del 25.4% y la mortalidad del 4.5%. Hubo una predicción buena en las complicaciones (complicación seria, estadística: $C: 0.725$,

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score Brier: 0.26, $p = 0.006$ y cualquier complicación, estadística: $C: 0.731$, score Brier: 0.33, $p = 0.005$) y la mortalidad (estadística $C: 0.922$, score Brier: 0.005, $p = 0.014$). **Conclusiones:** La aplicación de la calculadora ACS-NSQIP en pacientes sometidos a RH tiene buen poder de discriminación y buena habilidad predictiva. Predecir riesgos postoperatorios logra una adecuada planeación preoperatoria del procedimiento.

Palabras clave: Hepatectomía. Calculadora de riesgo. Morbilidad. Mortalidad. ACS-NSQIP.

Introduction

Hepatic resection (HR) is a healing therapeutic option for benign and malignant liver injuries. However, the morbidity and mortality of this procedure is still high^{1,2}. In an attempt to predict which patients can suffer morbidity and mortality in a HR, different factors have been evaluated, such as biochemical parameters (e.g.: serum bilirubin, prothrombin time, and albumin levels) and morbidity and mortality prediction models, which include Child-Pugh classification, the *American Society of Anesthesiologists* (ASA) classification, and the Model for End-stage Liver Disease (MELD)³⁻⁵.

An ideal prediction model should be easy to implement, include common and ordinary variables, be sensitive and specific, and should not generate an increase in financial and administrative terms. Furthermore, it should be used before surgery in order to provide information to the patient and achieve an adequate preoperative planning of the procedure⁶.

In this context, the American College of Surgeons (ACS) developed the Surgical Risk Calculator (SRC) of the National Surgical Quality Improvement Program (NSQIP), based on data from 3.8 million surgeries in 740 hospitals between 2012 and 2016⁷. This calculator can be accessed online: <http://riskcalculator.facs.org/>. This SRC calculates the risk for the patient for a specific procedure and it determines the postoperative results (morbidity and mortality 30 days after surgery). While the results of this calculator have been useful when predicting the risk of complications in patients, it has not been easy to apply it in populations outside of the original NSQIP cohort in different disciplines^{8,9}. In the case of liver surgery, the SRC has been shown in very few studies¹⁰⁻¹⁴.

The purpose of our study was to use and apply the SRC ACS-NSQIP in the prediction of complications after HR in a cohort of Mexican population.

Materials and methods

This is a retrospective study performed in a cohort of patients that underwent HR between January 2005 and

August 2019 in the city of Veracruz. The study was approved by the local research committees of the participating institutions. All HRs were performed by the same surgeon. Patients included in the study underwent HR due to benign, primary malignant, and metastatic diseases. Patients who underwent another procedure in addition to HR were excluded. Several sociodemographic variables, presence of concomitant conditions, as well as laboratory values. All patients with cirrhosis were evaluated using the same Child-Pugh classification and patients who underwent HR were included in the Child-Pugh A category.

Surgical risk calculator of the American College of Surgeons National Surgical Quality Improvement Program

The ACS-NSQIP SRC is a score system that generates an estimated percentage of risk up for up to 30 days after surgery, and the possibilities of certain complications. These results depend on the HR type (CPT codes: 47120-partial hepatectomy, 47122-trisegmentectomy, 47125-left hepatectomy, and 47130-right hepatectomy). This calculator estimates the risk of occurrence for the following results: serious complication, any complication, pneumonia, cardiac complication, surgical site infection, urinary tract infection, venous thromboembolism, acute kidney failure, re-admission in less than 30 days after surgery, reintervention, perioperative mortality (30 days), and discharge to a rehabilitation unit. The necessary patient data for the calculation are: procedure to be performed, age group, gender, functional status, emergency surgery, ASA, use of steroid for chronic conditions, presence of ascitis 30 days before surgery, presence of systemic sepsis 48 hours before procedure, depending on mechanical ventilation assistance, disseminated cancer, diabetes mellitus, hypertension, congestive heart failure 30 days before surgery, dyspnea, active tobacco use one year before surgery, severe chronic obstructive pulmonary disease, dialysis, acute kidney failure, height and weight. Access to SRC occurred on November 11, 2019.

Statistical analysis

Continuous variables were described as mean, standard deviation, and range. Categorical variables as frequencies and percentage. The statistical analysis included the ROC curve and Brier's *score*. The ROC curve establishes an area below the curve (C-statistic) which evaluates the predictive ability of the SRC in those complications that were present. The c-statistic represents the probability that an individual with the result of interest (complication and/or mortality) has a higher predictive probability than an individual without the result of interest (complication and/or mortality). A C-statistic value of 0.5 represents a randoms concordance, while a value of 1 indicated a perfect prediction ability. Brier's *score* measures the accuracy of probabilistic prediction. A *score* of 0 is associated with an exact probabilistic prediction. The average hospital stay observed in the cohort was compared to the average hospital stay obtained from the ACS-NSQIP calculator using the Z test in proportion of two populations with a two-tail hypothesis with a significance level of 0.05. A $p < 0.05$ was considered statistically significant. For the analysis of Brier's *score* the Excel *software* was employed, and all other analysis were performed with SPSS version 25.

Results

Sociodemographical data and values of the surgical risk calculator of the American College of Surgeons National Surgical Quality Improvement Program

The study included 67 patients of an average age of 51.9 ± 19.4 years (range: 18-82). 50.7% ($n = 34$) were females. The average body mass index was 26.9 ± 4.6 kg/m² (range: 18.9-39). Thirty-one patients (46.3%) had comorbidities, 6 (9%) has viral hepatitis (all with hepatitis C), and 19.4% ($n = 13$) had cirrhosis. The main laboratory data for the patients is found in table 1. The average MELD was 7.5 ± 1.7 points (6-13 range).

The majority of HRs (56.7%, $n = 38$) were indicated by malignant pathology. Among the patients who underwent HR due to malignity, 26.3% ($n = 10$) were due to metastasis and 28 patients (73.7%) were due to primary liver tumors. HRs due to benign pathology ($n = 29$, 43.3%) were primarily hemangiomas ($n = 22$, 75.8%), followed by adenomas ($n = 4$, 13.7%), trauma ($n = 2$, 6.8%) and a liver cysts (3.4%). The calculator values (ACS-NSQIP SRC) are shown on table 2.

Table 1. Main patient laboratory data ($n = 67$)

Laboratory	Value (mean $\pm$ SD) (range)
Hemoglobin (g/dl)	13 ± 1.3 (10.3-15.7)
Hematocrit (%)	38.8 ± 4.1 (29.6-45.7)
Leukocytes (cel./mm ³)	$8,685 \pm 9,052$ (3,600-66,000)
Platelets (cel./mm ³)	$248,093 \pm 92,575$ (83,300-527,000)
Prothrombin times (seconds)	13.03 ± 1.66 (10.9-18.1)
INR	1.05 ± 0.12 (0.87-1.4)
ALT (U/l)	63.9 ± 166.4 (9-1,202)
AST (U/l)	50.05 ± 71.12 (10-493)
ALP (U/l)	107.4 ± 43.3 (62-351)
Total bilirubin (mg/dl)	0.9 ± 1.03 (0.2-6.98)
Direct bilirubin (mg/dl)	0.53 ± 0.95 (0.08-5.68)
Albumin (g/dl)	4.03 ± 0.63 (1.5-5)
Glucose (mg/dl)	104.3 ± 51.9 (65-454)
Urea (mg/dl)	30.7 ± 15.5 (5.3-98.4)
Creatinine (mg/dl)	0.94 ± 0.35 (0.3-3.1)

ALT: alanine aminotransferase; ALP: alkaline phosphatase; AST: aspartate aminotransferase; cel.: cells; SD: standard deviation; INR: International Normalized Ratio.

Surgery results

41 partial hepatectomies (62.1%), 8 (11.9%) left hepatectomies, and 18 (26.9%) right hepatectomies were analyzed. Pringle's maneuver was used in 55.2% ($n = 37$) of cases with an average time of 18.1 ± 6.6 minutes (2-32 range). The average trans-operative bleeding was $1,106 \pm 1,216$ milliliters (range: 150-5,000). 44.8% ($n = 30$) were admitted to the intensive care unit and the average hospital stay was 8.2 ± 5.3 days (range: 2-32).

Perioperative morbidity was 25.4% ($n = 17$). The main complication was liver failure in 11.9% ($n = 8$), followed by reintervention in 6% ($n = 4$), surgical site infections in 4.5% ($n = 3$), pneumonia in 3% ($n = 2$), and cardiovascular events in 1.5% ($n = 1$) of cases. Postoperative mortality after 30 days was 4.5% ($n = 3$).

Results and analysis of the of the surgical risk calculator of the American College of Surgeons National Surgical Quality Improvement Program

Table 3 shows the average complication risks obtained by the ACS-NSQIP calculator, including the

Table 2. Variables used in the surgical risk calculator (SRC) of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)

Variable	n = 67 (100%)
Procedure	
47120-partial hepatectomy	41 (61.2%)
47125-left hepatectomy	8 (11.9%)
47130-right hepatectomy	18 (26.9%)
Age group	
< 65 years	45 (67.2%)
65-74 years	16 (23.9%)
75-84 years	6 (9%)
Gender	
Female	34 (50.7%)
Male	33 (49.3%)
Functional status	
Independent	42 (62.7%)
Partially independent	25 (37.3%)
Emergency surgery	
Yes	2 (3%)
No	65 (97%)
American Society Anesthesiologists classification	
I	17 (25.4%)
II	31 (46.3%)
III	19 (28.4%)
Use of steroids 30 days before surgery	
No	67 (100%)
Ascitis present 30 days before surgery	
Yes	5 (7.5%)
No	62 (92.5%)
Systemic sepsis 48 hours before surgery	
Yes	2 (3%)
No	65 (97%)
Mechanical ventilation assistance	
Yes	2 (3%)
No	65 (97%)
Disseminated cancer	
Yes	10 (14.9%)
No	57 (85.1%)
Diabetes mellitus	
Treatment with oral hypoglycemics	23 (34.3%)
Insulin treatment	2 (3%)
No	42 (62.7%)
Hypertension	
Yes	33 (49.3%)
No	34 (50.7%)
Congestive cardiac failure 30 days before surgery	
No	67 (100%)

(Continues)

Table 2. Variables used in the surgical risk calculator (SRC) of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) (continued)

Variable	n = 67 (100%)
Dyspnea	
No	67 (100%)
Active tobacco use in the same year as the surgery	
Yes	12 (17.9%)
No	55 (82.1%)
Chronic obstructive pulmonary disease	
No	67 (100%)
Dialysis	
No	67 (100%)
Chronic renal failure	
Yes	1 (1.5%)
No	66 (98.5%)
Weight categories	
Normal	26 (38.8%)
Overweight	26 (38.8%)
Level I obesity	9 (13.4%)
Level II obesity	6 (9%)

prediction for hospital stay. The risk of predicting a serious complication, the risk of predicting any complication, and the risk of predicting perioperative mortality had a statistically significant C-statistic value. The average of hospital stay days predicted by the ACS-NSQIP calculator was 6 ± 2.09 days (range: 3-18). There was no significant difference between the days of hospital stay observed in the cohort and those predicted by the calculator (Z-score: -0.056 , $p = 0.57$).

Discussion

The results of our study show that the ACS-NSQIP calculator has good performance in a cohort of Mexican patients undergoing HR, specifically when predicting general complications and mortality. There was no significant difference between the length of hospital stay observed and the length predicted by the calculator.

Predicting results in liver surgery has been described in single-center, multicentric studies, or national databases²⁻⁵. Prediction models have been developed based on laboratory, imaging and comorbidity values, for example. Prediction analysis plays an important role in the conversation between physician and patient when planning a surgical strategy. By having the opportunity

Table 3. Behavior analysis of the surgical risk calculator (SRC) of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)

Variable	Average risk (%)	C-statistic (AUC) (CI 95%)	p value	Brier score
	mean $\pm$ SD (range)			mean $\pm$ SD (range)
Serious complication	15.7 $\pm$ 8.08 (5.7-36.3)	0.725 $\pm$ 0.77 (0.574-0.877)	0.006*	0.26 $\pm$ 0.28 (0.01-1.25)
Any complication	17.9 $\pm$ 8.5 (6.8-37.1)	0.731 $\pm$ 0.76 (0.582-0.880)	0.005*	0.33 $\pm$ 0.33 (0.02-1.3)
Reintervention	2.6 $\pm$ 1.3 (1.1-7.3)	0.788 $\pm$ 0.13 (0.528-1.0)	0.055	0.002 $\pm$ 0.006 (0-0.04)
Surgical site infection	8.2 $\pm$ 2.8 (3.6-16.9)	0.531 $\pm$ 0.19 (0.155-0.908)	0.8	0.04 $\pm$ 0.04 (0-0.22)
Pneumonia	3.2 $\pm$ 4.4 (0.2-33)	0.473 $\pm$ 0.33 (0-1)	0.8	0.02 $\pm$ 0.11 (0-0.96)
Cardiovascular event	1.1 $\pm$ 1.1 (0-4.9)	0.902 $\pm$ 0.03 (0.829-0.974)	0.1	0.002 $\pm$ 0.001 (0-0.1)
Death	1.4 $\pm$ 2.21 (0-9.4)	0.922 $\pm$ 0.057 (0.81-1)	0.014*	0.005 $\pm$ 0.01 (0-0.07)

*Statistically significant.

AUC: are under the curve; CI 95%: confidence interval of 95%; SD: standard deviation.

to predict events, strategies can be employed to monitor these risks, from modifying the surgical approach, mobilizing resources, and closer postsurgical monitoring.

The cooperation of NSQIP in the US created an efficient system to monitor the institutional results from different procedures in order to improve patient care quality⁷. By means of the data analysis obtained by this calculator, surgeon can compare patient cohorts, determine areas of improvement, and make changes in our practice. Very few studies have evaluated and applied the ACS-NSQIP calculator outside of the institutions that participated in the creation of the original calculator in different disciplines, and liver surgery is no exception. In addition, the results of these application are controversial. Beal, et al.¹⁵ found a modest prediction (C-statistic between 0.6 and 0.7) of the results in liver surgery (especially surgical site infection, reoperation, readmission, and mortality) in addition to observing that the rate of observed events was higher than the event mean prediction. Others have used this calculator with good discrimination (C-statistic higher than 0.75) and have contrasted it with other models, finding that the NSQIP is superior¹³. Other have added other factors to the calculator, such as chronic liver failure¹¹ and, in some cases, they have used highly selected patient cohorts (hepatocarcinoma in the elderly) with poor prediction capacity and a inferior estimation of the risks¹⁴. These controversies have led authors, such as Pitt, et al.¹⁰ to propose specific options for hepatopancreatobiliary surgery within this calculator, or in other cases¹² creating specific center calculators in order to determine these risks in liver surgery. In our case, the calculator had good discrimination power in general terms (prediction of

complications) with a C-statistic higher than 0.7, however, in that area the Brier score was not as close to zero (which would be a perfect prediction). It is worth noting that mortality had an almost excellent calibration (> 0.9) and an almost perfect prediction ability. However, we can also say that the calculator performed an inferior estimation of our risks according to what was observed and, although this was not statistically significant, less hospital stay days.

Some of the considerations to take into account for these differences between the predictions of the calculator and the observations in the series of patients may be due to the time period of the study, the volume of cases in different years, the different hospitals where the procedures were performed, and the resources available to perform them. In these cases, we would need to find a way to include these differences in order to predict better results. Another limitation of the study could be the sample size, which is relatively limited, the diversity of procedures, and the capacity to predict all results, as not all were presented; however, the ACS-NSQIP calculator has standardized these procedures properly, eliminating possible deviations

Conclusions

The application of the ACS-NSQIP calculator in patients undergoing HR has good discrimination power and good predictive ability. Knowing and being able to predict postoperative risks provides information to the patient and achieves adequate preoperative planning of the procedure.

Conflicts of interest

The authors declare they have no conflicts of interest.

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Ethical disclosures

Protection of people and animals. The authors declare that no experiments have been made on human beings or animals for this research.

Data confidentiality. The authors declare that they have followed the protocols of their work center regarding the publication of patient data.

Right to privacy and informed consent. The authors declare that no patient data appears in this article.

References

1. Dokmak S, Fteriche FS, Borscheid R, Cauchy F, Farges O, Belghiti J. 2012 Liver resections in the 21st century: we are far from zero mortality. *HPB (Oxford)*. 2013;15:908-15.
2. Filmann N, Walter D, Schadde E, Bruns C, Keck T, Lang H, et al. Mortality after liver surgery in Germany. *Br J Surg*. 2019;106:1523-9.
3. Lorenzo CS, Limm WM, Lurie F, Wong LL. Factors affecting outcome in liver resection. *HPB (Oxford)*. 2005;7:226-30.
4. Mann CD, Palser T, Briggs CD, Cameron I, Rees M, Buckles J, et al. A review of factors predicting perioperative death and early outcome in hepatopancreaticobiliary cancer surgery. *HPB (Oxford)*. 2010;12:380-8.
5. Martínez-Mier G, Esquivel-Torres S, Alvarado-Arenas RA, Ortiz-Bayliss AB, Lajud-Barquin FA, Zilli-Hernández S. Liver resection morbidity, mortality, and risk factors at the departments of hepatobiliary surgery in Veracruz, Mexico. *Rev Gastroenterol Mex*. 2016;81:195-201.
6. Mansmann U, Rieger A, Strahwald B, Crispin A. Risk calculators—methods, development, implementation, and validation. *Int J Colorectal Dis*. 2016;31:1111-6.
7. Bilimoria KY, Liu Y, Paruch JL, Zhou L, Kmieciak TE, Ko CY, et al. Development and evaluation of the universal ACS-NSQIP surgical risk calculator: a decision aid and informed consent tool for patients and surgeons. *J Am Coll Surg*. 2013;217:833-42. e1-3.
8. Cologne KG, Keller DS, Liwanag L, Devaraj B, Senagore AJ. Use of the American College of Surgeons NSQIP Surgical Risk Calculator for laparoscopic colectomy: how good is it and how can we improve it? *J Am Coll Surg*. 2015;220:281-6.
9. Rivard C, Nahum R, Slagle E, Duinick M, Isaksson Vogel R, Teoh D. Evaluation of the performance of the ACS-NSQIP surgical risk calculator in gynecologic oncology patients undergoing laparotomy. *Gynecol Oncol*. 2016;141:281-6.
10. Pitt HA, Kilbane M, Strasberg SM, Pawlik TM, Dixon E, Zyromski NJ, et al. ACS-NSQIP has the potential to create an HPB-NSQIP option. *HPB (Oxford)*. 2009;11:405-13.
11. Zaydfudim VM, Kerwin MJ, Turrentine FE, Bauer TW, Adams RB, Stukenborg GJ. The impact of chronic liver disease on the risk assessment of ACS-NSQIP morbidity and mortality after hepatic resection. *Surgery*. 2016;159:1308-15.
12. Fruscione M, Kirks R, Cochran A, Murphy K, Baker EH, Martinie JB, et al. Developing and validating a center-specific preoperative prediction calculator for risk of outcomes following major hepatectomy procedures. *HPB (Oxford)*. 2018;20:721-8.
13. Madhavan S, Shelat VG, Soong SL, Woon WWL, Huey T, Chan YH, et al. Predicting morbidity of liver resection. *Langenbecks Arch Surg*. 2018;403:359-69.
14. Sahara K, Paredes AZ, Merath K, Tsilimigras DI, Bagante F, Ratti F, et al. Evaluation of the ACS-NSQIP Surgical Risk Calculator in elderly patients undergoing hepatectomy for hepatocellular carcinoma. *J Gastrointest Surg*. 2020;24(3):551-9.
15. Beal EW, Lyon E, Kearney J, Wei L, Ethun CG, Black SM, et al. Evaluating the American College of Surgeons National Surgical Quality Improvement project risk calculator: results from the U.S. Extrahepatic Biliary Malignancy Consortium. *HPB (Oxford)*. 2017;19:1104-11.