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The laparoscopic approach to distal pancreatectomy is a value-added proposition for patients undergoing care in moderate-volume and high-volume centers

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ABSTRACT

Background: Little is known regarding the impact of the minimally invasive approach to distal pancreatectomy on the aggregate costs of care for patients undergoing distal pancreatectomy.
Methods: We queried the Healthcare Cost and Utilization Project State Inpatient Database to identify patients undergoing elective laparoscopic distal pancreatectomy or open distal pancreatectomy between 2012 and 2014. Multivariable regression was used to evaluate postoperative outcomes including readmissions to 90 days after distal pancreatectomy.
Results: A total of 267 (11%) patients underwent laparoscopic distal pancreatectomy, and a total of 2,214 (89%) underwent open distal pancreatectomy. On multivariable regression, patients undergoing laparoscopic distal pancreatectomy had a decreased odds risk of having any severe adverse outcome (odds ratio 0.73, 95% confidence interval [0.54–0.97]), prolonged length of stay (odds ratio 0.49, 95% confidence interval [0.30–0.79]), and of being in the highest quartile for aggregate costs of care (odds ratio 0.46, 95% confidence interval [0.32–0.66]) relative to those undergoing open distal pancreatectomy. Patients undergoing laparoscopic distal pancreatectomy had a lower average 90-day aggregate cost of care than those undergoing open distal pancreatectomy when procedures were performed in high-volume (−$16,153, 95% CI: [−$23,342 to −$8,964]) centers.
Conclusion: Patients undergoing laparoscopic distal pancreatectomy have a lower risk of severe adverse outcomes, prolonged overall length of stay, and lower associated costs of care relative to those undergoing open distal pancreatectomy. This association is independent of hospital volume.

Introduction

United States healthcare spending grew 4% in 2017 alone, reaching $3.5 trillion, or $10,739 per person, and accounting for 18% of the national gross domestic product.[1] In 2015, 32% of the national healthcare expenditures went toward hospital-based care and 20% toward physician and clinical services.[1] Healthcare providers are under ever-increasing pressure to deliver value to patients by containing costs and continuing to provide high-quality clinical outcomes.

Distal pancreatectomy (DP) is a complicated surgical procedure that can be lifesaving but carries a significant risk of postoperative complication. The index procedure and hospitalization themselves are costly. Complications and related admissions and ancillary procedures necessary to manage complications frequently result in substantial increases in the costs of care. Because of the potential to save lives and the high costs of care associated with both the index operation and its postoperative complications, DP, by nature, represents a unique opportunity to significantly improve value for patients.

Studies have evaluated the impact of variations in several technical approaches to the DP on postoperative complication rates, rates of readmission, and lengths of stay.[2-4] These have

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included studies comparing minimally invasive methods with open procedures, use of staplers and various energy devices to divide the pancreatic parenchyma, use of endoscopic stenting to manage pancreatic fistula, and application of sealants to prevent fistula. Few of these studies evaluate the impact of varous technical approaches to distal pancreatectomy on the costs of care for patients undergoing DP. In the current study, we use the Healthcare Cost and Utilization Project State Inpatient Database to examine variations in aggregate costs of care associated with laparoscopic and open approaches to DP with results stratified by hospital volume.

Methods

Data source

The Healthcare Cost and Utilization Project State Inpatient Database was used to identify patients undergoing elective laparoscopic distal pancreatectomy (LDP) or open (ODP) distal pancreatectomy in Florida, Maryland, Massachusetts, New York, and Washington between 2012 and 2014. The Healthcare Cost and Utilization Project (HCUP) is an administrative data set composed of a family of healthcare databases developed through a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality. Each State Inpatient Database (SID) captures all inpatient discharges at nonfederal facilities for the respective state, regardless of primary payer. The SID includes patient-level demographic data, the Charlson comorbidity score, admitting diagnosis, procedures performed during the admission, and hospital volume for the procedure. The SID also captures readmissions after discharges and all associated procedure performed during those readmissions for any subsequent year of data that are made available by HCUP.

Study population

The analysis cohort included adult patients 18 years of age or older who were discharged from hospitals within their respective states after having undergone either an LDP or ODP. Patients were first identified as individuals having undergone DP for benign or malignant disease based on International Classification of Diseases, Ninth Revision (ICD-9) codes (157.1 body of pancreas, 157.2 tail of pancreas, 157.4 islets of Langerhans, 157.8 other specified sites of pancreas, 157.9 pancreas part unspecified, 577.1 chronic pancreatitis, 577.2 cyst and pseudocysts of pancreas, 577.8 other specified disease of pancreas, 577.9 unspecified disease of pancreas, 211.6 pancreas except islets of Langerhans, and 211.7 islets of Langerhans). This group was further divided by procedure type into 2 cohorts (those undergoing LDP and those undergoing ODP) by a secondary search from the DP cohort that underwent a surgical procedure based on ICD-9 codes (52.52 distal pancreatectomy,17.4–17.43 robotic-assisted, 54.21 laparoscopic). A total of 252 patients underwent conversion from LDP to ODP. Given data-set limitations, we were unable to identify the reason for a conversion from LPD to open ODP. We could not identify whether a conversion occurred as a part of a plan (diagnostic laparoscopy to rule out carcinomatosis after ODP) or as a result of an untoward intraoperative event. For this reason, we could not perform an intent-to-treat analysis and, to avoid related bias, we have elected to exclude patients undergoing a conversion from LPD to ODP from the data set.

Study design

This was a retrospective cohort study of patients undergoing distal pancreatectomy between 2012 and 2014. We intended to examine the association between surgical approach and aggregate in-hospital costs of care, including costs associated with the index procedure, index admission, and all readmissions up to 90 days after the index operation. Cost data were obtained using the HCUP total charges variable multiplied by a hospital-specific cost-to-charge ratio (CCR). The CCR is developed using standardized information on all-payer inpatient cost and charges reported by hospitals to the Centers for Medicare and Medicaid.

We also evaluated the association between surgical approach and rates of postoperative morbidity, readmission, and aggregate postoperative lengths of stay (LOS), including readmissions to 90 days after the index operation. The postoperative complications that were evaluated included myocardial infarction (MI), pulmonary embolism (PE), and sepsis. The overall LOS included all readmission to 90 days postindex procedure, and prolonged LOS was defined as a having an overall LOS greater than the 75th percentile for the entire DP population.

Statistical analysis

Baseline characteristics are presented as means with standard deviations, medians, and interquartile ranges, or counts and percentages. Variables included in univariate and multivariable analyses were determined a priori using best-variable subsets. Candidate variables included the following: age; sex; insurance type; race or ethnicity; Charlson comorbidity index (CCI); pathology (benign versus malignant); annual hospital DP volume broken into terciles low ($\leq$6 DPs/year), moderate (>6 and $\leq$41 DPs/year), and high volume (>41 DPs/year); and overall LOS, including all readmissions to 90 days postprocedure. Unadjusted comparisons of 2 or more proportions were performed using a χ^2 test. Continuous variables were compared using *t* tests or Wilcoxon rank-sum tests as appropriate. Multivariable regression (MVR) was used to evaluate the association between surgical approach and rates of postoperative complication (PE, MI, and sepsis), LOS, and aggregate costs of care including readmissions to 90 days after DP. All analyses were performed using STATA 14 software (StataCorp, College Station, TX). This study was evaluated and approved by the Institutional Review Board at Loyola University Chicago, Maywood, IL.

Results

Univariate comparison of demographics, LOS, mortality, and costs

A total of 4,481 patients underwent DP, a total of 267 (11%) patients underwent LDP, and a total of 2,214 (89%) underwent ODP. We observed no differences among the 2 cohorts in age, race or ethnicity, sex, and pathology. Compared with ODP, LDP patients had a higher frequency of private insurance (49% vs 42%, $P < .01$) and were more likely to have procedures performed in high-volume centers (35% vs 23%, $P < .01$). Patients undergoing LDP have a higher mean CCI (3 vs 2; $P < .01$) than those undergoing ODP (Table I). Compared with ODP, LDP patients also had shorter overall LOS (9 days, SD [7] vs 12 days, SD [14], $P < .01$), lower aggregated 90-day costs of care ($29,886 vs $41,385, $P < .01$), and lower frequency of postoperative complications (31% vs 38%, $P = .04$). We observed no difference in in-hospital death between the 2 groups (Table II).

Multivariable analysis of postoperative complications

We examined the postoperative outcomes for patients undergoing LDP compared with ODP to identify factors that may impact the in-hospital 90-day cost of care. On univariate analysis, patients

Table I
Demographic and pathologic characteristics of patients undergoing distal pancreatectomy*

	Open		Laparoscopic		*P*
Number patients, *n* (%)	2,214	89%	267	11%	
Age, mean (SD)	60	15	62	14	.09
Female sex, *n* (%)	1,219	55.1%	147	55.1%	1.00
Charlson comorbidity index, mean (SD)	2	2	3	3	< .01
Race/ethnicity, *n* (%)					
White	1,611	72.8%	205	76.8%	.27
Black	215	9.7%	28	10.5%	
Hispanic	187	8.4%	17	6.4%	
Other	201	9.1%	17	6.4%	
Insurance type, *n* (%)					
Medicare	992	44.8%	117	43.8%	.03
Medicaid	205	9.3%	16	6.0%	
Private	922	41.6%	129	48.3%	
Other	95	4.3%	—	1.9%	
Pathology, *n* (%)					
Malignant	848	38.3%	139	52.1%	< .01
Benign	1,366	61.7%	128	47.9%	
Annual hospital DP volume, terciles *n* (%)					
Low (1–5)	594	26.8%	49	18.4%	< .01
Moderate (6–41)	1,102	49.8%	124	46.4%	
High (> 41)	518	23.4%	94	35.2%	

LOS, length of stay; *DP*, distal pancreatectomy.
Note: Blank cells indicate data-use agreement restrictions.
* Data represent 2012–2014 for Florida, Maryland, Massachusetts, New York, and Washington.

Table II
Postoperative outcomes of patients undergoing distal pancreatectomy*

	Open		Laparoscopic		*P*
Overall morbidity,† *n* (%)	833	37.6%	83	31.1%	.04
Total LOS, mean (SD)	12	14	9	7	< .01
90-day readmission, *n* (%)	613	27.7%	61	22.8%	.09
In-hospital mortality, *n* (%)	28	1.3%			.85
90-day cost of care, mean (SD)	US$41,385	US$53,617	US$29,886	US$25,039	< .01

LOS, length of stay.
Note: Blank cells indicate data-use agreement restrictions.
* Data represent 2012–2014 for Florida, Maryland, Massachusetts, New York, and Washington.
† Overall morbidity includes pulmonary embolism, myocardial infarction, and sepsis.

undergoing LDP were less likely to have postoperative complications (PE, MI, and sepsis) and had shorter LOS and lower 90-day aggregate cost compared with patients undergoing ODP. On MVR, adjusted for age, sex, race or ethnicity, malignant pathology, insurance type, CCI, and hospital volume, LDP was associated with a lower odds risk of overall postoperative morbidity (OR 0.73, 95% CI [0.55–0.97]) and prolonged LOS (OR 0.49, 95% CI [0.30–0.79]) compared with ODP. We observed no statistical differences between the 2 cohorts in PE, MI, sepsis, and 90-day readmissions ($P > .05$; Table III).

Table III
Adjusted* odds risk of postoperative morbidity, readmission, and prolonged LOS for laparoscopic relative to open distal pancreatectomy

	OR	95% CI	
Postoperative morbidity			
PE	0.93	0.21	4.13
MI	—	—	—
Sepsis	0.59	0.30	1.15
Severe adverse outcome†	0.73	0.54	0.97
30-day readmission	0.80	0.59	1.09
90-day readmission	0.93	0.69	1.34
Prolonged LOS‡	0.49	0.30	0.79

LOS, length of stay; *PE*, pulmonary embolism; *MI*, myocardial infarction.
* Adjusted for age, sex, malignancy, Charlson index, race, insurance, volume, and procedure type.
† Severe adverse outcome includes cases where a patient developed a postoperative PE, MI, or sepsis.
‡ Prolonged LOS defined as greater than 75% of the overall length of stay (LOS).

Multivariable comparison of high-cost outliers

Next, we examined the risk factors associated with being a high-cost outlier after a DP. To qualify as a high-cost outlier, aggregate costs of care, including all readmissions to 90 days postindex procedure, had to be greater than those for the 75th percentile for the DP population. We aimed to identify any associations between being a high-cost outlier, surgical approach, and hospital volume. We performed an analysis adjusted for the following variables: age, sex, race or ethnicity, malignant pathology, CCI, insurance type, procedure approach, and hospital volume. The risk factors associated with being a high-cost outlier included the following: advanced age (OR 1.00, 95% CI [1.00–1.02]), male sex (OR 1.64, 95% CI [1.35–1.98]), CCI score (OR 1.25, 95% CI [1.19–1.31]), black race (OR1.56, 95% CI [1.14–2.13]), and Medicaid insurance (OR 1.54, 95% CI [1.09–2.18]). Compared with ODP, LDP patients had a significantly lower odds risk of being in the highest quartile of costs (OR 0.46, 95% CI [0.32–0.66]). We observed no significant association between hospital volume and the risk of being a high-cost outlier (Table IV).

Table IV
Adjusted odds risk of being a high-cost outlier after distal pancreatectomy*

	OR	95 % CI	
Age, (per year)	1.01	1.00	1.02
Male sex	1.64	1.35	1.98
Charlson comorbidity index	1.25	1.19	1.31
Malignant pathology	2.18	1.69	2.82
Race/ethnicity			
White (reference)			
Black	1.56	1.14	2.13
Hispanic	0.96	0.66	1.38
Other	1.14	0.82	1.60
Insurance type			
Private (reference)			
Medicare	1.05	0.81	1.36
Medicaid	1.54	1.09	2.18
Other	1.38	0.85	2.22
Surgical approach			
Open (reference)			
Laparoscopic	0.46	0.32	0.66
Annual hospital DP volume, *(terciles)*			
Low (1–5)	1.05	0.79	1.39
Moderate (6–41)	1.20	0.94	1.54
High (> 41; reference)			

DP, distal pancreatectomy.
* Adjusted for age, sex, malignancy, Charlson comorbidity index, race or ethnicity, insurance type, hospital volume, and procedure type.

The 90-day cost by hospital volume and approach

Finally, we attempted to define the relationship between hospital DP volume, surgical approach, and costs of care. Our hypothesis was that in hospitals performing a high volume of DP, the laparoscopic approach would be associated with lower aggregate costs of care than the open approach. On MVR analysis, adjusted for male sex, race or ethnicity, CCI, insurance type, malignant pathology, and age, patients undergoing LDP compared with patients undergoing ODP stratified by hospital volume, we found in high-volume centers (>41 DPs/year) that the laparoscopic approach resulted in lower cost than the open approach, with risk-adjusted savings of −$16,153 (95% CI: [−$23,342 to −$8,964]). In low-volume (1–5 DPs/year) and moderate-volume (>6 and ≤41 DPs/year) centers, there was no difference in the cost of care between laparoscopic and open approaches to a distal pancreatectomy (Table V).

Discussion

Pancreatic resections are technically complex operations that have high rates of postoperative morbidity. Very few studies to date have evaluated innovations in care for patients undergoing pancreatic resection from the perspective of the value proposition in healthcare. By nature, these operations are associated with high costs of care and have meaningful opportunities to provide value to patients by improving postoperative clinical outcomes in ways that are cost-effective. In this study, we aimed to examine the economic impact of applying the minimally invasive approach to DP by comparing the aggregate costs of care for patients undergoing LDP to a contemporaneous cohort of patients undergoing ODP. Our results revealed several interesting findings. In our adjusted analysis, compared with ODP, patients undergoing LDP had identical rates of PE, MI, and sepsis but had a lower risk of having a prolonged LOS, a severe adverse outcome, and of being in the highest quartile of cost. LDP patients had lower average aggregate costs of care when performed in high-volume centers; whereas, in low-volume to moderate-volume centers, cost was neutral when compared with ODP. These findings suggest that the laparoscopic approach is inherently cost neutral when compared with the open approach, but with experience, the fixed expense can be overcome to the point that the laparoscopic approach adds value to patients with pathology in the pancreatic tail, maintaining outcome quality but providing the outcome in a less costly manner.

Studies evaluating the relationship between 90-day costs and surgical approach in pancreatectomy are limited. Our principal finding suggests that the in-hospital 90-day costs for patients undergoing LDP in high-volume centers are less than that for patients undergoing ODP. A recent study by Ricci et al[5] found that patients undergoing LDP had similar postoperative complication rates and length of stay compared with patients undergoing ODP. The only difference noted between the 2 groups was that the laparoscopic group had an earlier return of bowel function and had a higher probability of being cost-effective.[5] The results of the Ricci et al[5] study are comparable with our postoperative complications, although we found that the LDP compared with the ODP approach was associated with a shorter LOS and was more cost-effective in high-volume centers. A study evaluating the cost in patients undergoing pancreaticoduodenectomy in high-volume centers by Tran et al[6] found that patients undergoing an LDP in high-volume centers had lower costs ($76,572 vs $106,367, $P < .01$) of care compared with patients undergoing OPD when comparing clinical outcomes at 30 days postprocedure.

In a national randomized comparison of clinical outcomes for LDP and ODP, de Rooji et al[7] found that 90-day costs were lower in patients undergoing LDP compared with ODP. This study was based in the Netherlands, with a patient population that is considerably more homogeneous than the population in our study and involves a single-payer healthcare system. The findings in that study may or may not be generalizable to populations with more heterogenous demographics and health systems that have fee-for-service reimbursement structures.[7] In a recent study using the Truven data set and examining 693 patients who underwent DPs, Fisher et al[8] found that LDP was associated with 90-day cost savings compared with OPD. Because of the limitations of that data set, the authors were unable to stratify by hospital volume or to study weather variation in complication rate was a potential driver of cost savings. Both of these variables are tracked in a meaningful way in the HCUP data set, and using the HCUP data set has allowed us to

Table V
Adjusted difference between aggregate costs of care for laparoscopic distal pancreatectomy and those for open distal pancreatectomy by facility volume*

	Unadjusted			Adjusted		
	Cost (US$)	95% CI (US$)		Cost (US$)	95% CI (US$)	
Number of cases per year, terciles						
Low (1–5)	−8,436	−27,046	10,174	−3,118	−21,806	15,570
Moderate (6–41)	−10,119	−19,697	−542	−9,444	−18,890	0.77
High (> 41)	−14,234	−21,515	−6,954	−16,153	−23,342	−8,964

* Adjusted for male sex, race or ethnicity, Charlson comorbidity index, insurance type, malignancy, and age.

comment on the way in which these variables contribute to costs of care.[8] In the current work, we found similar cost savings associated with the laparoscopic approach in DP. The advantage of our paper over the others is that we have evaluated clinical outcomes and costs to 90 days after the index procedure. Also, we stratified our results by hospital volume, which has not been done elsewhere. Patients undergoing pancreatectomy not infrequently accrue costs related to their complications for considerably longer than 30 days after the index procedure. Few studies are available regarding costs of care and drivers of value in hepatobiliary surgery. The advantage of using HCUP is that there is information from a broad population, a cross section of payers and providers that includes some data on complication rates. There are always limitations to use of any large data set for research but, recognizing these, we believe the observation of lower complication rates among the LDP cohort and lower associated costs of care is valid and meaningful. We are and increasingly will be asked as treating physicians to deliver value to patients. Value in healthcare may be best defined as quality per unit cost. Our results demonstrate that the laparoscopic method for DP adds value and should be used preferentially to ODP. For this reason, our result is likely more representative of the potential cost savings associated with the laparoscopic approach than earlier studies.

The underlying reasons for the cost savings associated with LDP are not readily apparent. We believe that the cost savings realized by LDP in high-volume centers are attributable in part to cost advantages that are achieved by economies of scale. As the number of procedures increases, the operators become more efficient with resources. High-volume surgeons likely have shorter operative times and use fewer disposable instruments (fewer staple loads, sutures, etc.) to do the procedures than do low-volume surgeons.[9] Other studies have noted that high-volume centers are more effective at rescuing patients from complications.[10,11] It is difficult to measure that type of an effect in HCUP because there are limited hospital-specific variables to evaluate this association, but it is possible that a better ability to rescue also contributes to lower costs at high-volume centers. Regardless of the underlying cause, the cost savings in high-volume centers is positive and would suggest that centralizing pancreatic surgical care to high-volume centers (regionally or locally) may lead to better value in the care of these patients.

We found that the laparoscopic approaches to DP are associated with a lower risk of developing postoperative complications. This observation is similar to studies that, in general, identify an association between the laparoscopic approach and lower rates of postoperative morbidity—lower blood loss and lower rates of delayed gastric emptying.[1,5,12-18] In a meta-analysis, Venkat et al[15] identified that LDP was associated with lower blood loss and no significant difference in operative time, margin positivity, the incidence of postoperative pancreatic fistula, or mortality compared with ODP. Our own earlier evaluation of postoperative outcomes has demonstrated that the laparoscopic approach is associated with less-severe adverse postoperative outcomes.[19] Our current study is unique in that we were able to validate that the laparoscopic approach has better outcomes to 90 days from the index surgery. We were unable to evaluate complications by hospital volume because there was a relatively low incidence of postoperative complication. The HCUP data set—without question—captures fewer complications that we would expect to find by a thorough retrospective chart review or in using the pancreas procedure target National Surgical Quality Improvement Program data set.

Our study has several limitations. These limitations have been discussed in greater detail in prior publications.[20,21] This study is a retrospective review of an administrative data set. We cannot definitively control or adjust for the selection biases that are inherent in these data sets. There is also a significant potential for omitted variable bias. The administrative data set does not contain detailed clinical information on many physiologic and pathologic measures that may contribute to patient selection for different interventions, determine outcomes, and affect costs of care. The data set does not offer granular detail on several postoperative complications that are relevant, the most notable being a pancreatic fistula. The data set does capture procedures used to manage complications (interventional radiology drain placement, intensive care unit admission, intubation, ventilation, return to the operating room). Those procedures and associated costs are included in the analysis. Given data set limitations, we were unable to perform an intent to treat analyses. Surgeon procedure volume is not tracked as a variable in HCUP. Because of this, we were only able to adjust for hospital volume. HCUP CCR cost data do not include professional (physician) fees, actual payments received, and postdischarge outpatient fees. Furthermore, HCUP does not include actual payments made to hospitals. Costs are, rather, derived by applying the cost-to-charge ratios to the charges reported by the hospitals. The data set does not track all complication types and cannot be directly linked to specific clinical activities. Given these limitations, future studies exploring cost, using more granular multi-institutional cost data, may add substantially to our understanding of the relationship between surgical approach and costs of care for these patients.

In conclusion, patients undergoing LDP have a lower risk of severe adverse outcomes, prolonged overall LOS, and lower associated costs of care relative to those undergoing ODP. This association is independent of hospital volume. This finding suggests that high-volume centers develop efficiencies of scale that allow them to realize aggregate cost savings when utilizing laparoscopic approaches to DP and also suggest that the laparoscopic approach adds value beyond that provided by the open approach to DP for patients with pathology in the pancreatic tail.

Conflict of interest

The authors have indicated that they have no conflict of interest regarding the content of this article.

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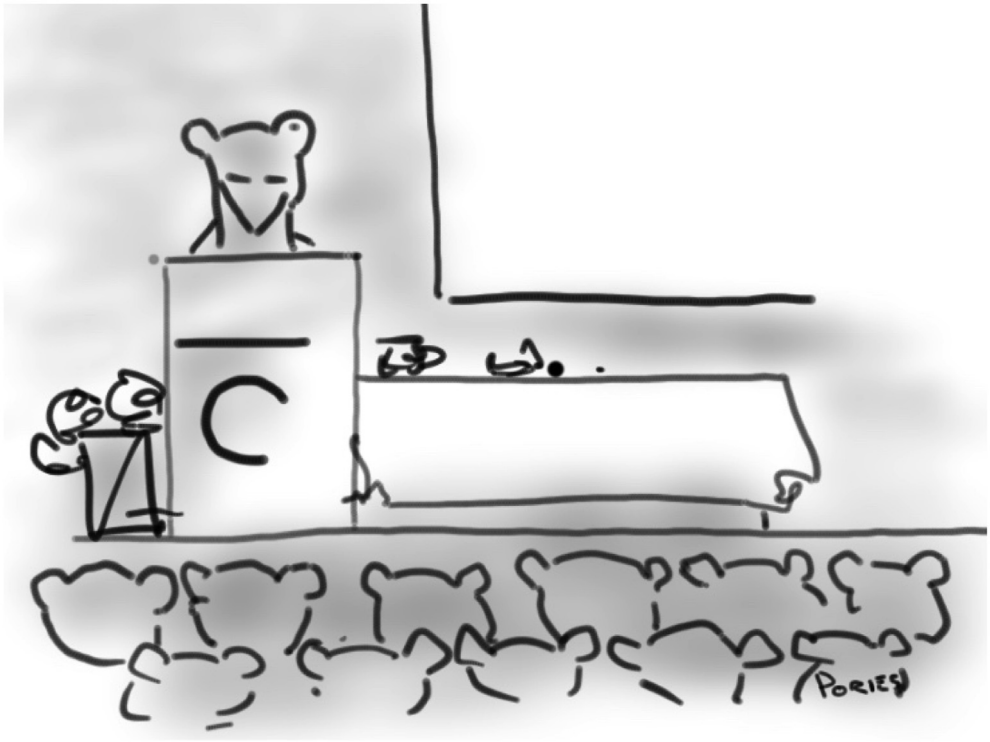

"In view of these severe adverse events in humans, I cannot, in good conscience, approve this drug for rodents."