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Percutaneous cholecystostomy for grade III acute cholecystitis is associated with worse outcomes

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ABSTRACT

Background: The aim of the present study was to evaluate the mortality, morbidity, and readmissions associated with management of grade 3 cholecystitis in the elderly, vulnerable population.

Methods: This was a retrospective cohort study of non-elective admissions for acute cholecystitis from 2010 to 2015 using the nationwide readmissions database for adults $\geq$ 65 years with evidence of end-organ dysfunction (grade 3) who underwent percutaneous cholecystostomy (PC), laparoscopic (LC) or open cholecystectomy (OC). Index and readmission outcomes were analyzed using logistic regression and inverse probability treatment weight analysis.

Results: Of the estimated 358,624 patients, 14.9% underwent PC, 15.7% OC, and 69.4% LC. PC had significantly higher odds of mortality (AOR 5.8, 95%CI 5.1–6.6), composite morbidity (AOR 3.8, 95%CI 3.5–4.1), early (AOR 1.9, 95%CI 1.7–2.0) and intermediate (AOR 2.2, 95%CI 2.0–2.5) readmission compared to LC and OC.

Conclusions: Patients undergoing cholecystostomy had higher mortality, complications, and readmission rates warranting revaluation of criteria for cholecystostomy at initial presentation.

Introduction

The Tokyo Guidelines were established to help guide the management and stratify the severity of acute cholecystitis.[1] Such stratification scheme is particularly important in the elderly who have a relatively high burden of acute cholecystitis, lack physiologic reserve, and are at elevated surgical risk due to multiple comorbidities. Although the past two decades have seen major advances in the management of the critically ill, elderly patients continue to suffer death rates that are 2–3 fold higher following cholecystectomy for acute cholecystitis. Thus, this cohort presents a challenge in clinical decision making and management of acute cholecystitis.[2–6]

The management of grade III cholecystitis, defined as being associated with end organ dysfunction, remains controversial. Percutaneous cholecystostomy (PC) has emerged as an alternate to definitive cholecystectomy, and in fact is the first line recommendation according to the Tokyo Guidelines.[7] As a result, PC is increasingly utilized in patients considered at high risk for conventional cholecystectomy. However, the Tokyo Guidelines are based on expert opinion rather than Level 1 evidence. Indeed, most reports on the short and medium term outcomes of PC have been retrospective, limited by small sample size, or are dated studies making definitive conclusions on its efficacy questionable.[8–10] More recent studies have revealed that the majority of patients managed with PC require repeated hospitalizations, do not ultimately receive a cholecystectomy, and exhibit a mortality of ~10% in the year following PC.[11–15]

As the US health care system has transitioned from episodic care to bundled payments for disease states, the principle of value has emerged as a global measure of performance. The concept of value-

Abbreviations: PC, Percutaneous Cholecystostomy; LC, Laparoscopic Cholecystectomy; OC, Open Cholecystectomy; NRD, Nationwide Readmissions Database; AHRQ, Agency for Healthcare Research and Quality; IPTW, Inverse probability for treatment weighting; LVH, Low Cholecystectomy Volume Hospital; HVH, High Cholecystectomy Volume Hospital.

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ratio of quality to costs of patient care-is particularly relevant to the care of frail and high-risk patients such as those targeted in the Tokyo Guidelines. While the acute procedural mortality of PC is low due to avoidance of general anesthetic, this technique does not definitely remove inflamed and potentially necrotic tissue. Therefore, the present study used a contemporary national sample to evaluate the acute clinical outcomes and costs for elderly patients admitted for acute cholecystitis and end organ dysfunction managed by PC or cholecystectomy. We further examined rehospitalizations and clinical outcomes of delayed cholecystectomy based on initial management strategy. We hypothesized increased morbidity, mortality, readmissions, and costs associated with PC compared to OC and LC.

Methods

This was a retrospective analysis of data obtained from the 2010–2015 Nationwide Readmissions Database (NRD), the largest publicly available all-payer discharge database maintained by the Agency of Healthcare Research and Quality (AHRQ).[16] Patient data are extracted from individual State Inpatient Databases with unique patient identifiers to allow for visit linkage of all inpatient facilities, excluding rehabilitation and long-term acute hospitals.[16] Discharge-weights assigned to each sampled institution allow for survey-weighted national estimates that account for up to 57.8% of all US discharges.

The study cohort was derived from the approximately 36 million annual weighted discharges in the NRD using International Classification of Disease (ICD9) and ICD10 administrative coding. All elderly adults (≥65 years) admitted non-electively (NRD "elective" variable) with a diagnosis of cholecystitis in the first three available diagnosis fields with end-organ dysfunction were considered (Supplemental Fig. 1). Procedure codes were utilized to identify patients who underwent PC, open cholecystectomy (OC), or laparoscopic cholecystectomy (LC), excluding those who underwent both cholecystostomy and cholecystectomy during the same admission as well as patients who were converted from laparoscopic to an open approach. Grade III cholecystitis was defined using methods previously described by Dimou et al. (Supplemental Table 1).[6] Patients who underwent cholecystectomy in the first four months or PC in the last four months of each calendar year were excluded to avoid incorrect characterization of interval cholecystectomy as primary cholecystectomy. Length of the exclusion period was calculated as three-standard deviations from the mean interval from PC discharge to cholecystectomy in the cohort. Furthermore, patients who did not undergo PC, OC, or LC were excluded from the analysis.

Comorbidities were characterized using the available ICD9 and 10 diagnosis codes. A composite malignancy variable was generated using ICD coding that included thoracic, gastrointestinal, musculoskeletal, gynecologic, urologic, and hematologic diagnoses. Elixhauser Comorbidity Index was used as a validated method of characterizing patient comorbidity over the study period.[17] We adopted the Johns Hopkins Frailty Score to further characterize frailty status.[18,19] Annual institutional cholecystectomy volume was calculated, with hospitals within the highest volume tertile designated as High Volume Hospitals (HVH). Hospitals in the lowest tertile of cholecystectomy volume were used as reference in comparisons with HVH. NRD provided variables were used to characterize transfer status and admission to non-index hospitals. Time to cholecystectomy and cholecysostomy were calculated, but given significant missingness in procedure temporal information, time to intervention was not included in multivariable analyses.

The primary study outcome was ≤30 day (*early*) and 31–90 day (*intermediate)* readmission following elderly admission for grade III cholecystitis requiring intervention. Secondary outcomes were index mortality, composite morbidity defined as neurologic, cardiovascular, thromboembolic, respiratory, and infectious complications; hospitalization costs; and length of stay (LOS). Readmission diagnoses were categorized based on grouping of similar Diagnoses-Related-Group codes for all patients with a linked, non-elective second visit within 30- and 31–90 days of discharge from the index hospitalization for cholecystitis.

Demographics were compared using chi-squared analysis between the *PC, OC, and LC groups* for categorical variables and student's t-test for continuous variables with alpha <0.05 established as significant. Royston's chi-square test of trend was used to evaluate trends in PC, OC, and LC utilization among the elderly cholecystitis population that required intervention over the study period.[20] Multivariable logistic models were generated for categorical outcomes of mortality, as well as early or intermediate nonelective readmission using survey weighted analyses to account for hospital clustering effects. Readmission mortality was also examined in the subgroup of patients who received PC at the index hospitalization. Model selection was based on inclusion of clinically relevant variables as well as those with $P < 0.2$ on univariate comparisons in order to optimize the C-statistic. Incremental length of stay (LOS) and cost analysis was performed using linear regression models with LC as the reference group. Odds ratios (OR) were reported with corresponding 95% Confidence Interval (95% CI). The Kaplan-Meier method was used to illustrate time to readmission performance. Wilcoxon Log-rank test was used to evaluate discrepancies in readmission performance amongst the PC, LC, and OC patients who survived to discharge.

Inverse probability of treatment weighting was also used to address treatment-selection bias. Inverse probability weights (IPW) were generated using multi-level mixed-effect logistic regression predicting treatment with PC using patient and hospital characteristics detailed in Supplemental Table 1. A new patient-level weight was generated using the product of NRD provided "discwt" and the calculated IPW. Survey-weighted multivariable regression examining outcomes of interest, including mortality, *early* and *intermediate* readmissions, and costs were then replicated to complete a sensitivity analysis, accounting for baseline comorbidity imbalance. All statistical analyses were performed using Stata 15 (StataCorp, College Station, Tx). This study was deemed exempt from review by the Institutional Review Board at the University of California, Los Angeles.[1–4]

Results

Of an estimated 358,624 elderly patients admitted nonelectively with cholecystitis, 29.8% demonstrated features of grade III cholecystitis, of whom 14.9% underwent PC, 15.7% OC and 69.4% LC (Supplemental Fig. 1). Over the study period, the proportion of patients who underwent OC significantly decreased from 20.3% to 11.7% ($P < 0.001$), the rate of PC rose from 9.0% to 17.8% ($P < 0.001$), while LC utilization exhibited a relatively steady trend (67.7–63.5%, $P < 0.001$) Fig. 1(). Overall patient comorbidity, measured by the average Elixhauser Comorbidity Index, increased slightly (3.9–4.1, Ptrend <0.001). Patients who underwent PC were on average older and more likely to be at the highest quartile of the Elixhauser Comorbidity Index compared to OC and LC patients (Table 1). PC patients had the highest prevalence of frailty and cholangitis, with the lowest rate of concurrent acute pancreatitis (Table 1). Furthermore, malignancy was more prevalent in the PC cohort compared to OC and LC as shown in Table 1. After risk-adjustment, elderly patients with grade III cholecystitis and malignancy (AOR 1.6, 95% CI 1.5–1.9), frailty (AOR 2.0, 95% CI 1.8–2.1), or heart failure (AOR 1.8, 95% CI 1.7–1.9) had the greatest odds of

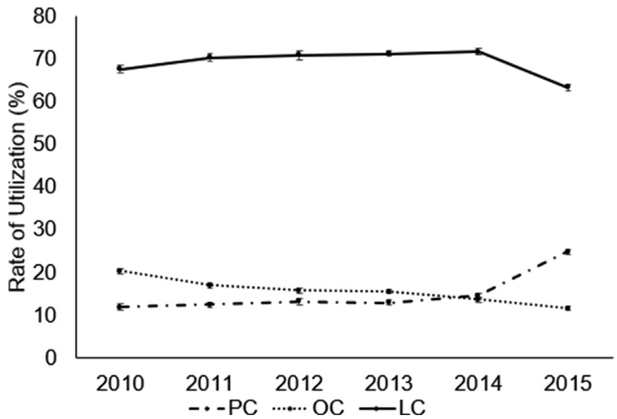

Fig. 1. Rate of Procedure Utilization for Patients Age ≥65 years admitted non-electively with Grade III cholecystitis.
*Ptrend<0.001 for PC, OC, and LC.
Standard error represented with error bars.

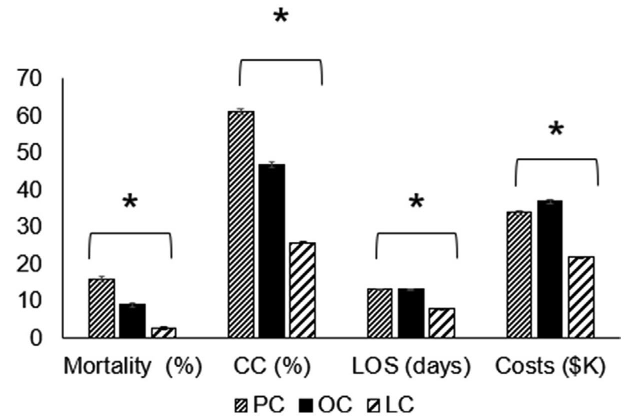

Fig. 2. Unadjusted Index Hospitalization Outcomes
Standard error represented with error bars. *P < 0.001.

receiving cholecystostomy (Supplemental Table 2).

Unadjusted index mortality and composite complication rates were lowest for LC compared to OC and PC (Fig. 2). PC also had the highest utilization of non-home discharge and use of home health services compared to OC and LC (Fig. 3). After adjusting for institutional cholecystectomy volume, transfer status, frailty, and patient comorbidities, including malignancy, acute pancreatitis, and cholangitis, PC and OC had significantly higher odds of inpatient mortality and composite morbidity compared to LC (Fig. 4). Frailty was also associated with significantly higher risk-adjusted mortality (AOR 1.6, 95% CI 1.4–1.8). Furthermore, OC ($10,722, 95% CI $9,777–11,667) but not PC was associated with significantly higher risk-adjusted incremental index costs when LC was used as the reference operation, accounting for occurrence of pancreatitis and cholangitis. In contrast, both OC (3.9 days 95% CI 3.6–4.2 days) and PC (2.7 days, 95% CI 2.4–3.0 days) were associated with increased LOS compared to LC. The above multivariable results were confirmed after application of inverse probability treatment weights (Supplemental Fig. 2).

As shown in Supplemental Fig. 3, unadjusted early and intermediate readmission rates were higher in the PC cohort compared to OC and LC. After risk-adjustment, PC and OC had greater odds of early readmission compared to LC, while only PC was associated with increased odds of 31–90 day rehospitalization (Fig. 4 and Supplemental Fig. 2). Over the remaining calendar year, a higher proportion of PC patients were rehospitalized at least once compared to OC and LC (P < 0.001) (Fig. 5). All-together, 22.5% of those readmitted following PC within 30- days and 41.3% between 31 and 90 days had biliary complaints, which significantly exceeded

Table 1
Patient and hospital characteristics.

	PC N = 15,884 (%)	OC N = 16,801 (%)	LC N = 74,144 (%)	P-Value
Mean Age, years (SE)	79.2 (0.09)	77.3 (0.08)	77.3 (0.04)	<0.001
Female Gender	40.6	39.4	45.0	<0.001
Heart Failure	35.0	22.6	21.7	<0.001
Chronic Obstructive Pulmonary Disease	25.1	22.7	21.3	<0.001
Diabetes with systemic complications	10.1	8.0	9.4	0.002
Renal Dysfunction	44.1	40.4	48.6	<0.001
Chronic Liver Disease	3.3	6.2	6.4	<0.001
Obesity	13.7	15.6	15.5	0.006
50th Percentile Elixhauser Comorbidity Index	65.3	55.6	58.0	<0.001
Acute Pancreatitis	6.9	11.1	19.0	<0.001
Cholangitis	8.4	6.5	6.5	<0.001
Malignancy	8.0	6.7	4.3	<0.001
Frailty	33.9	26.5	17.6	<0.001
Transfer	7.1	7.0	4.2	<0.001
Cholecystectomy Volume Tertiles				
LVH	33.6	37.4	34.9	0.64
MVH	34.1	32.0	33.6	
HVH	32.2	30.6	31.5	
Hospital Metropolitan Status[a]				
Large metropolitan area ≥1 million residents	59.5	49.1	50.8	<0.001
Small metropolitan area ≤1 million residents	34.9	39.8	38.7	
Micropolitan area	5.0	8.9	8.8	
Rural	0.5	2.2	1.6	
Hospital Teaching Status				
Metropolitan non-teaching	29.5	41.7	47.2	<0.001
Metropolitan teaching	64.9	47.1	42.3	
Non-metropolitan teaching	5.6	11.1	10.5	

[a] NRD predefined variable of "HOSP_URCAT4"; LVH = Low volume hospital, MVH = High volume hospital, HVH= High volume hospital; 50th percentile Elixhauser Comorbidity Index (ECI) represents a categorical value for patients with a mean ECI at or higher than the 50th percentile for the entire population.

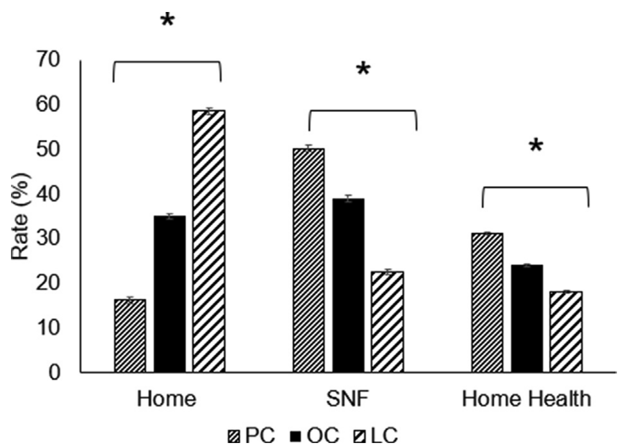

Fig. 3. Disposition after Index Hospitalization for Grade III Cholecystitis in the Elderly. Standard error represented with error bars. *P < 0.001.

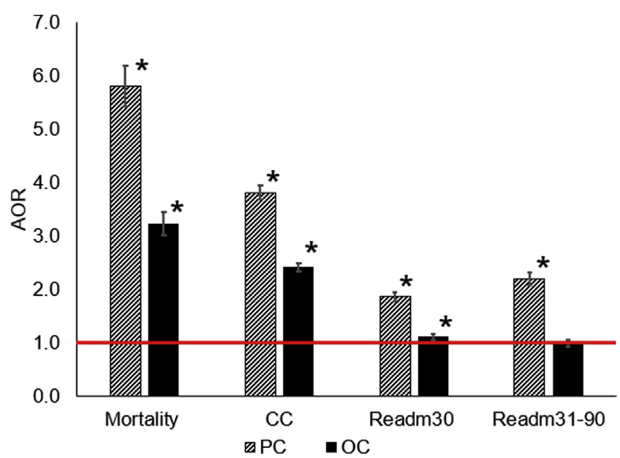

Fig. 4. Adjusted Index and Readmission Outcomes.
Standard error represented with error bars. *P < 0.001
*LC as reference operation indicated by horizontal line.

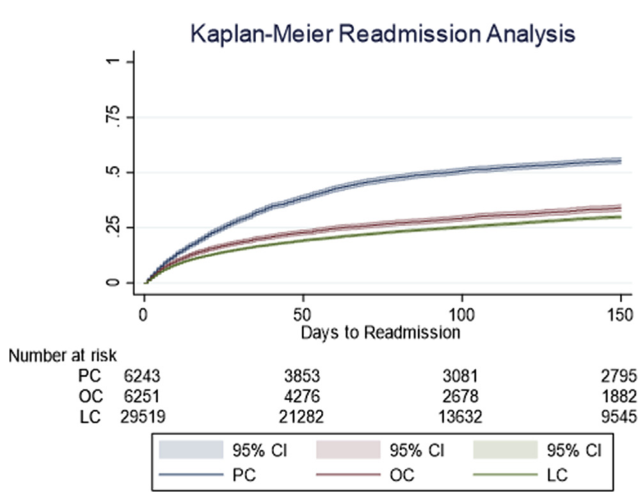

Fig. 5. Readmission Analysis by Cholecystitis Management Strategy.
*OC vs PC and LC vs PC Log-rank test P < 0.001.

biliary readmissions for OC (30 day: 5.5% and 31–90 day: 6.1%) and LC (30 day: 7.2% and 31–90 day: 6.7%) (P < 0.001). Cardiovascular and respiratory indications for readmission comprised over 20% of readmissions within 30 days for all three groups, with a higher prevalence among LC patients (Table 2).

Of all patients who received PC at index hospitalization and survived to discharge (13,341), 19.2% returned for laparoscopic or open cholecystectomy by the end of the year, with 74.5% of interval cholecystectomy occurring at the first readmission. On average, the second hospitalization for cholecystectomy was 50 days from index discharge with no difference in time to OC or LC (53.4 vs 47.3 days, P = 0.05). Female gender (AOR 0.70, 95% CI 0.58–0.85), history of heart failure (AOR 0.62, 95% CI 0.51–0.76), chronic liver disease (AOR 0.43 95% CI 0.22–0.84), and frailty (AOR 0.67, 95% CI 0.54–0.82) were associated with decreased odds of undergoing OC or LC after PC. Compared to PC patients with multiple readmissions, interval cholecystectomy at the first readmission following PC was associated with lower odds of readmission mortality (AOR 0.52, 95% CI 0.34–0.81, C-Statistic 0.64). Furthermore, interval-LC was associated with lower readmission mortality compared to interval-OC in patients initially treated with PC (OR 0.42, 95% CI 0.0.20–0.86, C-Statistic 0.76). Cumulative costs at 3 months were significantly higher for PC ($46,773) compared with LC ($26,118) and OC ($41927) patients (P < 0.001).

Discussion

Elderly patients with biliary disease are at markedly increased risk of death following cholecystectomy.[21] Despite the maturation of laparoscopic cholecystectomy as a surgical technique and advances in critical care, patients with organ dysfunction represent a very high-risk cohort who may be unfit for cholecystectomy. The Tokyo Guidelines, based on expert opinion and small reported series, recommend such patients to be treated via early PC.[1,7,10] Such an approach might lead to less physiologic derangement by circumventing general anesthesia and its associated cardiovascular risks. Unlike cholecystectomy, however, PC simply drains the gallbladder and does not remove the main culprit for the disease, raising concerns about its true benefits and cost-efficiency. The present study provides a contemporary assessment of rates and outcomes of cholecystostomy utilization in the elderly with grade III cholecystitis at the national level and yields several noteworthy findings. First, utilization of PC has increased, supplanting open cholecystectomy, while the utilization of LC remained relatively stable. Of all patients who undergo PC, a low proportion return for definitive cholecystectomy as an inpatient. And finally, PC was associated with increased odds of index mortality, morbidity, and readmissions.

The increased rate of PC observed in this retrospective study is consistent with several other reports including Cherng and Dimou et al.[6,22] While reasons for this trend may be multi-factorial, the potential influence of the Tokyo Guidelines warrants discussion. Aimed at reducing the mortality and complications associated with the disease, a series of Tokyo Guidelines have provided recommendations in the management of cholecystitis and the use of early drainage. Based on expert consensus, the Tokyo Guidelines have suggested the routine use of PC instead of cholecystectomy in patients with end organ dysfunction. Using the available variables in the database, we did not observe a change in patient factors during the study, suggesting rapid adoption of PC as the main driver for its use. After adjusting for available confounders, we found the use of PC to be associated with increased mortality, complications and costs at the index hospitalization. We also examined factors influencing the choice of PC and found malignancy, heart failure, and frailty to be predictive. In line with Tokyo Guidelines to avoid major

Table 2
Most Common Readmission Diagnoses for Early (30 day) and Intermediate (31–90 day) Readmissions.

	30-Day			P-value*	31–90 Day			P-value*
	PC	OC	LC		PC	OC	LC	
	(N = 3,876) (%)	(N = 2,515) (%)	(N = 9,423) (%)		(N = 2,702) (%)	(N = 971) (%)	(N = 4,274) (%)	
Hepatobiliary	22.5	5.5	7.2	<0.001	41.3	6.1	6.7	<0.001
Infectious	18.4	24.1	17.7	0.7	16.1	16.0	12.4	0.02
Cardiac	12.3	15.1	17.3	<0.001	9.0	16.7	17.0	<0.001
Gastrointestinal	9.9	18.3	18.7	<0.001	7.2	13.9	13.7	<0.001
Respiratory	8.4	8.4	9.3	0.4	4.9	5.4	8.6	0.004
Complication**	6.2	4.0	2.4	<0.001	2.9	0.2	0.9	0.002
Renal Failure	6.0	7.0	5.6	0.2	3.4	7.7	5.9	0.001
Neurologic	2.3	2.6	4.2	0.004	1.5	6.2	4.6	<0.001

*P-value comparing PC and LC.
**DRG 919–921, general admission DRG describing procedural complication.

operations in frail patients, long terms results need to be examined in a randomized fashion. Abi-Haidar and Hall et al. shared our findings in smaller/single institutional cohorts.[23,24] Despite the higher use of PC at LVH, institutional volume did not correlate with primary or secondary outcomes, suggesting that this widely performed procedure may require more granular thresholds not feasible in the present analysis. Whether the apparent increase in mortality and resource use with PC during the index stay is driven by higher patient burden of disease deserves further investigation.

Until recently, few have reported on the readmission burden after PC outside of single center studies. The reported readmission rates have ranged between 20 and 40% and are consistent with the findings of the present study.[11,25,26] Dimou and colleagues used Medicare data and showed increased readmissions associated with PC in a propensity matched cohort of 563 cholecystostomy matched to 1,689 controls.[6] Other retrospective studies of the NRD, while suffering from severe limitations in methodology, yielded similar findings of increased rehospitalization with PC.[27] Moreover, the present study excluded patients who received PC in the first four months of the year, decreasing the risk of incorrectly defining interval cholecystectomy patient who may have undergone PC in the final months of the preceding year. Using rigorous statistical methods, we have demonstrated PC to be associated with increased risk of readmission compared to LC/OC in elderly patients with grade III cholecystitis.

In the present study, interval cholecystectomy following PC was detected nearly half as frequently as previously reported. While others have found a 52% interval cholecystectomy rate, this discrepancy might be due to the limited ability of NRD to only capture inpatient hospitalizations.[9,12] Our findings are consistent with another NRD study of all adults, showing that two in three patients who undergo PC do not undergo eventual definitive cholecystectomy.[28] This limitation is tempered by the clinical consideration that elderly patients requiring PC at index hospitalization are less likely to undergo outpatient procedures due to possible frailty, comorbidity, or disease severity that precluded definitive therapy in the first place.

Few have compared expenditures in the management of acute cholecystitis with PC versus cholecystectomy. A randomized clinical trial of patients initially treated with PC found LC in the same hospitalization to yield cost savings compared to delayed LC(-$1,123).[29] Furthermore, the burden of readmission costs after PC compared to index LC has remained generally uncharacterized. Recently, a limited NRD study found that patients who underwent PC at index hospitalization to have lower costs of index hospitalization but higher overall costs.[27] The present study demonstrates increased index and readmission costs with the use of PC compared to LC. Our findings are exclusive to a high-risk cohort with complex acute cholecystitis and are likely more representative of the population targeted by the Tokyo Guidelines.

Our study has several important limitations inherent to its retrospective nature and use of an administrative database. Given that linkage numbers are not uniform throughout each year of the NRD, the duration of follow-up is limited for operations that occurred towards the end of the year. Furthermore, the NRD captures inpatient hospitalizations, thus limiting our ability to estimate total costs of care. Although physiologic and laboratory data is not available in NRD, we used previously validated statistical methods including accurate coding to discern severity of acute and chronic diseases.[6] Despite adjusting for patient frailty, transfer status, and institutional cholecystectomy volume in multivariable and inverse probability treatment weight analysis, we acknowledge that outcomes may reflect baseline differences in patient comorbidity. Given the limitations of NRD, we were not able to capture outpatient mortality of PC or cholecystectomy and could not report cumulative mortality.

Conclusion

In summary, using a nationally representative inpatient database, we found rapid adoption of PC across the US. Use of PC was associated with increased mortality and costs in elderly patients with Grade III acute cholecystitis even after adjusting for baseline differences. Furthermore, PC was associated with increased rehospitalization and cumulative costs of care. More stringent criteria are necessary to identify patients who truly have prohibitive risk of definitive cholecystectomy at initial presentation. Randomized trials evaluating the role of PC in high-risk patients are warranted and should focus on cumulative resource use and patient centered outcomes.

Author disclosure statement

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this manuscript.

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Declaration of competing interest

Authors have no potential conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.11.025.

References

1. Takada T, Kawarada Y, Nimura Y, et al. Background: Tokyo Guidelines for the management of acute cholangitis and cholecystitis. *J Hepatobiliary Pancreat Surg*. 2007;14(1):1–10. https://doi.org/10.1007/s00534-006-1150-0.
2. Kirshtein B, Bayme M, Bolotin A, Mizrahi S, Lantsberg L. Laparoscopic cholecystectomy for acute cholecystitis in the elderly. *Surg Laparosc Endosc Percutaneous Tech*. 2008;18(4):334–339. https://doi.org/10.1097/SLE.0b013e318171525d.
3. Brunt LM, Quasebarth MA, Dunnegan DL, Soper NJ. Outcomes analysis of laparoscopic cholecystectomy in the extremely elderly. *Surg Endosc*. 2001;15(7):700–705. https://doi.org/10.1007/s004640000388.
4. Dobson GP, Faggian G, Onorati F, Vinten-Johansen J. Hyperkalemic cardioplegia for adult and pediatric surgery: end of an era? *Front Physiol*. 2013;4:228. https://doi.org/10.3389/fphys.2013.00228.
5. Agrusa A, Romano G, Frazzetta G, et al. Role and outcomes of laparoscopic cholecystectomy in the elderly. *Int J Surg*. 2014;12:S37–S39. https://doi.org/10.1016/J.IJSU.2014.08.385.
6. Dimou FM, Adhikari D, Mehta HB, Riall TS. Outcomes in older patients with grade III cholecystitis and cholecystostomy tube placement: a propensity score analysis. *J Am Coll Surg*. 2017;224(4):502–511. https://doi.org/10.1016/J.JAMCOLLSURG.2016.12.021. e1.
7. Yokoe M, Takada T, Strasberg SM, et al. New diagnostic criteria and severity assessment of acute cholecystitis in revised Tokyo guidelines. *J Hepatobiliary Pancreat Sci*. 2012;19(5):578–585. https://doi.org/10.1007/s00534-012-0548-0.
8. Byrne MF, Suhocki P, Mitchell RM, et al. Percutaneous cholecystostomy in patients with acute cholecystitis: experience of 45 patients at a US referral center. *J Am Coll Surg*. 2003;197(2):206–211. https://doi.org/10.1016/S1072-7515(03)00143-1.
9. Bala M, Mizrahi I, Mazeh H, Yuval J, Eid A, Almogy G. Percutaneous cholecystostomy is safe and effective option for acute calculous cholecystitis in select group of high-risk patients. *Eur J Trauma Emerg Surg*. 2016;42(6):761–766. https://doi.org/10.1007/s00068-015-0601-1.
10. Okamoto K, Suzuki K, Takada T, et al. Tokyo Guidelines 2018: flowchart for the management of acute cholecystitis. *J Hepatobiliary Pancreat Sci*. 2018;25(1):55–72. https://doi.org/10.1002/jhbp.516.
11. Fleming MM, Liu F, Luo J, Zhang Y, Pei KY. Predictors of 30 d readmission following percutaneous cholecystostomy. *J Surg Res*. 2019;233:1–7. https://doi.org/10.1016/J.JSS.2018.07.006.
12. Chang YR, Ahn Y-J, Jang J-Y, et al. Percutaneous cholecystostomy for acute cholecystitis in patients with high comorbidity and re-evaluation of treatment efficacy. *Surgery*. 2014;155(4):615–622. https://doi.org/10.1016/J.SURG.2013.12.026.
13. Mizrahi I, Mazeh H, Yuval JB, et al. Perioperative outcomes of delayed laparoscopic cholecystectomy for acute calculous cholecystitis with and without percutaneous cholecystostomy. *Surgery*. 2015;158:728–735. https://doi.org/10.1016/j.surg.2015.05.005.
14. Boules M, Haskins IN, Farias-Kovac M, et al. What is the fate of the cholecystostomy tube following percutaneous cholecystostomy? *Surg Endosc*. 2017;31(4):1707–1712. https://doi.org/10.1007/s00464-016-5161-x.
15. Loftus TJ, Collins EM, Dessaigne CG, et al. Percutaneous cholecystostomy: prognostic factors and comparison to cholecystectomy. *Surg Endosc*. 2017;31(11):4568–4575. https://doi.org/10.1007/s00464-017-5517-x.
16. *HCUP: Overview of the Nationwide Readmissions Dataase (NRD)*; 2014. https://www.hcup-us.ahrq.gov/nrdoverview.jsp.
17. Van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the elixhauser comorbidity measures into a point system for hospital death using administrative data. https://insights.ovid.com/pubmed?pmid=19433995. Accessed August 16, 2017.
18. Green AR, Leff B, Wang Y, et al. Geriatric conditions in patients undergoing defibrillator implantation for prevention of sudden cardiac death: prevalence and impact on mortality. *Circ Cardiovasc Qual Outcomes*. 2016;9(1):23–30. https://doi.org/10.1161/CIRCOUTCOMES.115.002053.
19. Michel J, Goel AN, Golla V, et al. Predicting short-term outcomes after radical cystectomy based on frailty. *Urology*. July 2019. https://doi.org/10.1016/j.urology.2019.04.057.
20. Royston P. PTREND: Stata module for trend analysis for proportions. *Stat Softw Components*; October 2014. https://ideas.repec.org/c/boc/bocode/s426101.html. Accessed January 15, 2018.
21. Kuy S, Sosa JA, Roman SA, Desai R, Rosenthal RA. Age matters: a study of clinical and economic outcomes following cholecystectomy in elderly Americans. *Am J Surg*. 2011;201(6):789–796. https://doi.org/10.1016/J.AMJSURG.2010.04.018.
22. Cherng N, Witkowski ET, Sneider EB, et al. Use of cholecystostomy tubes in the management of patients with primary diagnosis of acute cholecystitis. *J Am Coll Surg*. 2012;214(2):196–201. https://doi.org/10.1016/J.JAMCOLLSURG.2011.11.005.
23. Abi-Haidar Y, Sanchez V, Williams SA, Itani KMF. Revisiting percutaneous cholecystostomy for acute cholecystitis based on a 10-year experience. *Arch Surg*. 2012;147(5):416–422. https://doi.org/10.1001/archsurg.2012.135.
24. Hall BR, Armijo PR, Krause C, Burnett T, Oleynikov D. Emergent cholecystectomy is superior to percutaneous cholecystostomy tube placement in critically ill patients with emergent calculous cholecystitis. *Am J Surg*. 2018;216(1):116–119. https://doi.org/10.1016/J.AMJSURG.2017.11.002.
25. Sanjay P, Mittapalli D, Marioud A, White RD, Ram R, Alijani A. Clinical outcomes of a percutaneous cholecystostomy for acute cholecystitis: a multicentre analysis. *HPB*. 2013;15(7):511–516. https://doi.org/10.1111/j.1477-2574.2012.00610.x.
26. Flexer S, Peter M, Durham-Hall A, Ausobsky J. Patient outcomes after treatment with percutaneous cholecystostomy for biliary sepsis. *Ann R Coll Surg Engl*. 2014;96(3):229–233. https://doi.org/10.1308/003588414X13814021679799.
27. Fleming MM, DeWane MP, Luo J, Liu F, Zhang Y, Pei KY. A propensity score matched comparison of readmissions and cost of laparoscopic cholecystectomy vs percutaneous cholecystostomy for acute cholecystitis. *Am J Surg*. 2019;217(1):83–89. https://doi.org/10.1016/J.AMJSURG.2018.10.047.
28. Pavurala RB, Li D, Porter K, Mansfield SA, Conwell DL, Krishna SG. Percutaneous cholecystostomy-tube for high-risk patients with acute cholecystitis: current practice and implications for future research. *Surg Endosc*. October 15, 2019.
29. Gurusamy KS, Rossi M, Davidson BR. Percutaneous cholecystostomy for high-risk surgical patients with acute calculous cholecystitis. *Cochrane Database Syst Rev*. 2013;8. https://doi.org/10.1002/14651858.CD007088.pub2.