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EARLY CLINICAL AND ECONOMIC OUTCOMES OF EXPANDED CRITERIA LIVING KIDNEY DONORS IN THE UNITED STATES

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Abstract

Background: The donation of what might be termed expanded criteria kidneys has become an increasingly common practice. This study aimed to assign expanded criteria and non-expanded criteria donation status and examine early clinical and economic outcomes among expanded criteria and non-expanded criteria living kidney donors (LKDs) hospitalizations in the US.

Methods: HCUP-NIS data (Jan 2008-Dec 2019, N=12020) was used. Expanded criteria LKDs were identified as admissions who were aged ≥60 years, or 50–59 years with any comorbidity that historically precluded donation. The Clavien-Dindo system was applied to classify surgical complications as grade I-IV/V.

Results: The number of LKD admissions decreased by 31% over the study period, although this trend fluctuated over time. Compared to non-expanded criteria LKD admissions, expanded criteria LKD admissions had comparable surgical complication rate in Grade I (aOR 1.0, 0.8-1.3), but significantly higher surgical complication rates in Grade II (aOR 1.5, 1.1-2.2) and Grade III (aOR 1.4, 1.0-2.0). The two groups had comparable hospital length of stay and cost in the adjusted models. Notably, complication Grade II was significantly higher in private, for-profit hospitals (15%) compared to government hospitals (2.9%).

Conclusions: Expanded criteria LKDs had comparable early outcomes compared to non-expanded criteria LKDs, but the trends evident in LKDs over time and the variation in complication records warrant further research.

Key words: economic outcomes, expanded criteria kidneys, living donor, surgical complications

Introduction

Kidney transplantation is the optimal form of renal replacement therapy for end-stage renal disease (ESRD) [1]. Expanding the available donor pool by encouraging living kidney donation has become common practice to address the global organ shortage and save lives [2]. The positive outcomes for kidney transplant recipients as well as evidence of safety for kidney donors have been central to the promotion of living kidney donation [3]. As ESRD becomes more prevalent and medical technology advances, the practice of procuring kidneys from what are variously referred to as “expanded criteria”/“extended criteria”/“marginal” donors has increased [3, 4]. Expanded criteria living kidney donors (LKDs) include older individuals [5, 6] or those with comorbidities such as diabetes [7], obesity [5], or hypertension [8], conditions that would previously have precluded their candidature as donors [9]. However, most studies on outcomes of expanded criteria LKD focused on renal function and graft survival in transplant recipients [10], only a few reported outcomes of older kidney donors [11, 12].

Regarding kidney transplantation, the United Network for Organ Sharing (UNOS) has provided a definition for expanded criteria kidney donation from *deceased* donors [13]. Currently, there is no unified definition for extended/expanded criteria LKDs [9] Although Massie et al. (2016) proposed a Live Donor Kidney Transplantation Risk Index, this study has not provided a cut-off to define expanded criteria LKDs [14]. Criteria that have been used to identify expanded criteria LKDs are older age or having comorbidities that typically exclude them from being eligible to donate a kidney (such as diabetes, hypertension, obesity, or abnormalities in kidney function or structure) [9]. However, a survey by Lafranca et al. reported remarkable variability in practices regarding extended criteria LKDs among transplant experts [15].

Early clinical outcomes including the risk of complications following donation surgery are important factors to be considered and communicated with potential living donors. The validated Clavien-Dindo system has been commonly used to categorise and evaluate the seriousness and potential consequences of surgical complications [16, 17]. This system classifies surgical complications as Grade I (*any deviation from the normal postoperative course without the need for pharmacological treatment or further interventions*), Grade II (*requiring pharmacological treatment with drugs other than such allowed for grade I complications*), Grade III (*requiring surgical, endoscopic or radiological intervention*), and Grade IV/V (*life-threatening complication or death*) [16, 17].

In this study, we compared early clinical outcomes (surgical complications as classified by Clavien-Dindo system) and economic outcomes (length of stay in the hospital [LOS] and hospital costs) between expanded criteria and non-expanded criteria LKDs using inpatient data in the US from 2008 to 2019. The aim of the study was to compare outcomes and changes in these over time with a view to informing policymaking and future research.

Methods

Data source

Data were obtained from the Healthcare Cost and Utilization Project- National (Nationwide) Inpatient Sample (HCUP-NIS), Agency for Healthcare Research and Quality (AHRQ) for 12 years, January 2008 to December 2019 [18]. HCUP-NIS is the largest all-payer inpatient care database in the US with roughly 7 million hospital admissions annually, representing an approximately 20% sample of discharges from

all HCUP community hospitals, excluding rehabilitation and long-term acute care hospitals [18].

In HCUP-NIS data, each hospitalization is recorded with up to 35 diagnoses and 25 procedures using (in the period under examination) the International Classification of Diseases 9th (ICD9) codes and ICD10 codes. LKDs were defined as elective admissions with a primary diagnosis of kidney live donor (ICD9 code: V59.4, ICD10: Z52.4) and a primary procedure of nephroureterectomy (ICD9 code: 55.51, ICD10: 0TT00ZZ, 0TT04ZZ, 0TT10ZZ, 0TT14ZZ). While a clear definition of expanded criteria LKDs is lacking, they are often considered as having characteristics that would historically have precluded living donation, including older age and having comorbidities. In this study, expanded criteria LKDs were identified as admissions for individuals who were aged ≥60 years, or 50–59 years with any comorbidity that normally precludes them from being a donor (comprising diabetes, obesity, hypertension, nephrolithiasis, and kidney cysts) [9]. Diabetes, obesity, and hypertension were coexisting medical conditions pre-defined by HCUP data using AHRQ comorbidity software which based on ICD diagnoses and the Diagnosis Related Group (DRG) in effect on the discharge date [18]. Nephrolithiasis and kidney cysts were defined using ICD diagnoses.

HCUP-NIS data provide additional predefined characteristics of each hospitalization including age at admission (years), sex (male, female), race (White, Black, Hispanic, Asian, Native American, Other races), income quartile (based on median household income for patient's ZIP Code), insurance type (Medicare, Medicaid, private insurance, and others), location (broadly in terms of rurality), hospital control/ownership, and hospital size (based on the number of hospital beds). A Deyo-Charlson Comorbidity Index (CCI) was developed based on ICD codes for each patient’s episode of care

[19]. A limitation of the data is that admissions cannot be linked, thus it is not possible to identify individuals with more than one admission in a given year.

Data analysis

Clinical outcomes

Surgical complications were examined. The Clavien-Dindo system was applied to classify complications as grade I, grade II, grade III, and grade IV/V [16]. The ICD9 algorithm developed by Lentine et al. (2016) was applied to HCUP data to abstract admissions with any surgical complication classified by the Clavien-Dindo system [20]. Multivariable logistic regression models were used to examine the likelihood of having surgical complications of expanded criteria LKD admissions compared to non-expanded criteria LKD admissions, adjusted for other covariates.

Economic outcomes

Based on the relatively normal distribution of hospital LOS, a multivariable linear regression model was used to examine LOS between groups. Hospital charges were converted to costs using the 'cost-to-charge' ratio tool provided by AHRQ-HCUP[18] and adjusted for inflation using the personal consumption expenditure health component price index [21]. Generalized linear models with log link and gamma family were used to accommodate the continuous, positive and skewed nature of hospital cost data in the cost analysis.

A survey-specific methodology was applied to account for the complex design and sampling method of HCUP-NIS data and ensure national representativeness [22]. HCUP-NIS data were weighted using trend weight for data years prior to 2012 and by the discharge-level weight for data from 2012 and later as recommended by AHRQ [18].

Results

Descriptive statistics

Fourteen admissions (0.12%) were excluded due to uncertainty in secondary diagnosis. Of these, six had a kidney cancer diagnosis, which might be related to the nephrectomy procedure, eight were both kidney donors and liver donors. The resulting sample was 12,020 admissions, equivalent to a population estimate of 58,908 LKD admissions over the 12-year period, January 2008 to December 2019 (95% confidence interval [CI] 54,218-63,597). The annual number of LKD admissions in HCUP data subtantially decreased between 2008-2012 while fluctuating between 2013-2019, and the ptrend test showed a significant downward trend over time ($p < 0.001$). Meanwhiles, the annual number of expanded criteria LKD admissions fluctuated slightly, leading to an increase in the percentage of expanded criteria LKD admissions from 8.7% in 2008 to 14.5% in 2019 (Fig 1), peaking in 2018 (18%). The percentage of admissions with complications in any Clavien-Dindo grade ranged from 10.4% (2018) to 21.6% (2010) among LKD admissions, and from 12.9% (2015) to 35.9% (2010) among expanded criteria LKD admissions (Fig 1).

Fig 1. Number of admissions having LKDs record over time (2008-2019)

(A) Number of admissions having LKDs record and Clavien-Dindo surgical complications, total LKDs and expanded criteria LKDs

(B) Percentages of expanded criteria LKDs, complications among expanded criteria and non-expanded criteria LKDs

Table 1 presents descriptive statistics. Expanded criteria LKD admissions accounted for 11.7% of all LKD admissions (95%CI: 11.0%-12.5%). A majority of LKD admissions were female (62%), White (66.6%), from areas with the highest income quartile (31.3%) and had private insurance (45.1%). The comorbidity index was relatively low

(mean 0.06, standard deviation [SD] 0.28) and the percentages with diabetes, obesity and hypertension were 0.2%, 5.2%, and 4.7%, respectively. Most of the living kidney transplantation procedures were performed in private (not-for-profit) hospitals (72.1%) and large hospitals (based on number of beds [18], 86.4%). Compared to non-expanded criteria LKDs, expanded criteria LKDs were more likely to be White, live in areas with higher income, have higher comorbidity indexes, and have obesity and hypertension. The most common surgical complications were gastrointestinal (4.5%), respiratory (2.2%), and bleeding (1.6%). Surgical complications in any Clavien-Dindo grade accounted for 14.8% among non-expanded criteria LKD admissions and 17.1% among expanded criteria LKD admissions, wherein Grade I was most common.

Table 1. Descriptive statistics of the studied cohort, non-expanded criteria vs. expanded criteria LKD admissions

Clinical outcomes

Regarding the whole studied sample, the number of admissions having surgical complications classified as Grade I, Grade II, Grade III, and Grade IV/V were 923 (7.7%), 440 (3.7%), 364 (3.0%), and 53 (0.4%), respectively (Table 1). The corresponding national estimates were 4538 (7.7%), 2328 (4.0%), 1905 (3.2%), and 256 (0.4%) for Grade I, Grade II, Grade III, and Grade IV/V, respectively.

In Table 2, Clavien-Dindo Grade III and IV/V groups were combined due to small cell counts. Compared to non-expanded criteria LKD admissions, expanded criteria LKD admissions had comparable percentages of surgical complications Grade I (8.1% vs. 7.6%) and Grade II (3.9% vs. 4.1%), and higher percentage of surgical complications from Grade III (5.8% vs. 3.2%). After adjustment for a range of covariates, the aOR of having complication Grade I, II, and III or higher were 1.0 (95%CI: 0.8-1.3), 1.5 (1.1-

2.2) and 1.4 (1.0-2.0) among expanded criteria LKD admissions compared to non-expanded criteria LKD admissions, respectively.

In the adjusted models, factors associated with increased likelihood of complications Grade II were private, for-profit hospitals (aOR 8.8, 95%CI 3.2-24.7) compared to government hospitals, large hospital (aOR 7.8, 95%CI 1.7-35.9) compared to small hospital, having obesity (aOR 1.4, 95%CI 1.0-1.9) compared to no obesity recorded. Factors associated with increased likelihood of complications Grade III or higher were older vs. younger age (aOR 1.02, 1.00-1.03, p<0.01) and having Medicare insurance vs. other insurances (aOR 1.7, 1.2-2.3, p<0.01). Being female was associated with lower likelihood of having complication Grade I (aOR 0.8, 0.7-0.9, p<0.01) compared to male.

Table 2. Surgical complications (classified by Clavien-Dindo grade)

Economic outcomes

Length of stay in the hospital

Expanded criteria (mean 2.5 days, SD 1.2) and non-expanded criteria (mean 2.6 days, SD 1.2) LKD admissions had comparable LOS for the nephrectomy surgery (Table 3). After adjustment for other covariates, there was no difference between the two groups. Regarding other factors, having private insurance or living in the area with highest income quartile were associated with shorter LOS, while having higher CCI (0.3 days, 95%CI 0.14-0.46, p<0.001) and having surgical complications (0.88 days, 95%CI: 0.74-1.01, p<0.001) were associated with longer LOS.

Hospital incurred cost

Compared to non-expanded criteria LKD admissions, expanded criteria LKD admissions had higher hospital costs in the unadjusted model (estimated effect: $755,

95%CI 339-1171, p<0.001), although this effect was not significant at 5% level in the adjusted model. In the adjusted model, having higher CCI vs. lower CCI ($685, 95%CI 242-1129), obesity vs. no obesity ($784, 186-1383), hypertension vs. no hypertension ($756, 188-1394), surgical complications in any Clavien-Dindo grade vs. none ($1525, 903-2146), and living in areas with higher income quartiles were associated with increased hospital costs. On the other hand, having private insurance, having the surgery performed in private, for-profit hospital, or in medium-sized/large-sized were associated with lower hospital costs (see Table 3).

Table 3. Factors associated with increased/decreased LOS and hospital incurred cost

Discussion

The current population-based retrospective cross-sectional study reports that expanded criteria LKD admissions accounted for 11.7% of LKD admissions (95%CI: 11.0%-12.5%), which increased from 8.7% (2008) to 14.5% (2019).

The surgical complication rate overall was 14.7% (13.1-16.5%) compared to the reported 18.4% complication rate in the previous study [23], indicating a downward trend despite increasing rates of obesity (5.2% vs. 2%) between the two periods.

The Clavien-Dindo classification of complications Grade I, Grade II, Grade III, and , Grade IV/V accounted for 7.7%, 3.7%, 3.0%, and 0.4% of surgical complications, respectively. A recent study reported complication rates of 2.4%, 2.6%, 5.2%, and 2.4% for Grade I, II, III, and IV/V, respectively [24]. It is obviously not possible to have a ‘zero’ risk nephrectomy and common complications in Grade I and II will occur in a minority of cases. It is encouraging that the rate of complications, requiring anything more than pharmacological intervention (grade III, IV, and V), is uncommon.

Of great interest is whether the living donor with comorbidity retains similarly good short-term clinical outcomes. In this study, although the surgical complication rates of Grade I severity were comparable between expanded criteria and non-expanded criteria LKD admissions (aOR 1.0, 95%CI: 0.8-1.3), there was a significantly higher surgical complication rate in Grade II (aOR 1.5, 1.1-2.2) and Grade III (aOR 1.4, 1.0-2.0) categories for expanded criteria LKD admissions.

It is notable, however, that the definition of an expanded criteria LKD has not been officially established, unlike in deceased donation. In broad terms it may be considered as potential donors who historically would not have been considered suitable to donate, and in this paper included those ≥60 years old, or 50-59 years old with one of diabetes, obesity, hypertension, nephrolithiasis, and kidney cysts. However, while it is biologically plausible that older patients (with reduced physiological reserve) and those with obesity will be at higher risk of surgical complications, the presence of hypertension or a structural renal abnormality would not routinely be expected to confer an increased short-term risk. Agreement and clarity about which clinical features render a living donor as 'expanded criteria' is urgently required. Consideration should also be given as to whether the 'expanded criteria' are in relation to the donor, or the recipient, or both.

In this study, surgical complications grade II were more likely to be recorded in private, for-profit hospitals (15%) compared to government (public) hospitals (2.9%), with aOR 8.8 (95%CI:3.2-24.7), there was no significant difference between public and private non-profit hospitals. Eappen et al. (2013) reported a close relationship between complications and hospital revenue due to higher proportion of per-encounter hospital cost reimbursed by payers [25]. That the system rewarded on postoperative complications rather than quality improvement [26] is also evident in case of kidney

transplantation, which mostly happened in private hospitals. Analogous to diagnosis-related group (DRG) upcoding, it may be that a combination of financial incentives and smaller volume of procedures, combine to produce higher complication rates in this type of hospital. Further studies are needed to address this question given the potentially erroneous information it may provide to would-be kidney donors.

In expanded criteria LKD admissions with complications of any grade, the estimated cost was $15,628 (95%CI 14,679-16,577) compared to $14,121 (95% CI 13,536-14,705) for those without complications. In fact, having any complications were associated with an average increase of $1,525 (95%CI 898-2,153) in hospital costs, and of 0.88 days (0.74-1.01) in LOS compared to those without complications. Another study found surgical complications could account for 9.8% of long-term postoperative complications among LKDs [27], which confirmed the importance of reducing these [20, 27]. Surgical complications are inevitable and may increase with the use of patients that are more obese and those with diabetes. The volume of LKD surgery at transplant centers may afford the best means for minimising complications and thereby potentially enhance not only clinical but also economic outcomes of LKDs.

The study observed a downward trend in the number of LKD hospitalizations over the study period (ptrend < 0.001). Although this trend was less obvious after 2018, this was not able to be confirmed as data on 2020 was not used in the current study due to the potential bias related to COVID-19. Crude comparison between 2019 and 2008 numbers showed 31% deccrease in the number of LKD admissions. This finding is consistent with the fluctuations in annual number of LKDs reported by the US Organ Procurement and Transplantation Network (OPTN), although the estimates obtained from HCUP-NIS seemed marginally lower than OPTN estimates [28]. Rodrigue et al. (2013) proposed several potential explanations for this decline including changes in

policy related to the allocation of kidneys from deceased donors by UNOS, the increasing tendency to evaluate the performance of transplant centers, the decreasing health status of general population which leads to a smaller donor pool, and the economic crisis during 2007-2008 period [29]. Although it is not possible to directly link these hypotheses to what is observed in this study, our findings could be considered as supportive of Rodrigue and colleagues' arguments. A recent study (2021) underlined the lack of progress in expanding kidney transplantation in the US despite various policy reforms, public awareness campaigns, and extensive research [30]. Policy related to improving kidney transplantation activities to save lives is thus important.

Limitations

HCUP data are cross sectional and do not allow patient admissions to be linked. Therefore, the outcomes presented in this paper are confined to the observed admissions without considering readmissions. Most importantly, a clear definition of extended or expanded criteria living kidney donation is lacking. This lack of consensus is likely to result in differences in selection of LKDs between countries, centers, and even among transplant experts within each center. Finally, other factors such as center-effect, out-of-pocket costs of donors, donors' costs due to lost income/productivity, the long-term outcomes, and mental health impacts cannot be ascertained from the studied dataset.

In contrast to the overall downward trend in the number of LKDs over time, the number of expanded criteria LKDs was maintained. The increase in relative percentage of this cohort necessitates an understanding of the early clinical and economic outcomes.

Expanded criteria LKDs have comparable hospital LOS, and costs. While the risk of serious complications remains low, it is higher than for non-expanded criteria LKDs.

Additionally, we observed more postoperative complications among admissions in for-profit compared to not-for-profit hospitals. It might be beneficial for policy makers to examine if the outcomes are grounded in different selection criteria or throughput in for-profit hospitals and to consider developing policies aimed at promoting LKDs.

List of Abbreviations

Term	Meaning
95%CI	95% confidence interval
AHRQ	Agency for Healthcare Research and Quality
aOR	Adjusted odds ratio
CCI	International Classification of Diseases
DRG	Diagnosis-related group
ESRD	End-stage renal disease
HCUP-NIS	Healthcare Cost and Utilization Project- National (Nationwide) Inpatient Sample
ICD	International Classification of Diseases
LKDs	Living kidney donors
LOS	Length of stay in the hospital
OPTN	US Organ Procurement and Transplantation Network
OR	Odds ratio
SD	Standard deviation
UK	United Kingdom
UNOS	United Network for Organ Sharing
US	United States of America

Declarations

Ethics approval and consent to participate

This study was considered exempt by the School Research Ethics Committee/Institutional Review Board at Queen's University Belfast due to the anonymised and publicly available nature of HCUP-NIS data.

Availability of data and materials

The data underlying this study belong to the Agency for Healthcare Research and Quality (AHRQ). The National Inpatient Sample (NIS) data are publicly available for

purchase through the AHRQ Healthcare Cost and Utilization Project (HCUP) (https://www.hcup-us.ahrq.gov/tech_assist/centdist.jsp). Data are available to all researchers following a standard application process and all signing of a Data Use Agreement. The authors paid a fee to access the NIS data used in this study (HCUP-NIS from 2008 to 2019) in accordance with the HCUP Central Distributor regulations (https://www.distributor.hcup-us.ahrq.gov/). Future researchers interested in purchasing and using HCUP databases will be required to complete the Web-based HCUP Data Use Agreement (DUA) Training (https://www.hcup-us.ahrq.gov/tech_assist/dua.jsp). Instructions for submitting an application for purchasing HCUP Databases could be found at https://www.distributor.hcup-us.ahrq.gov/.

Competing interests and Funding

The authors declare that they have no competing interests. The authors did not receive support from any organization for the submitted work.

Authors' contributions

All authors contributed to the study conception and design. NTQN and CO participated in research design, material preparation, data analysis, and writing the first version of the manuscript. NTNQ, CO, QEC, HQN, MQ, APW participated in the revising of the paper and the performance of the research. All listed authors agreed with the final version of the manuscript.

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Tables

Table 1. Descriptive statistics of the studied cohort, non-expanded criteria vs. expanded criteria LKD admissions

	Non-expanded criteria LKDs	Expanded criteria LKDs	p-value	Total
Age (years), Mean (SD)	39.8 (10.4)	61 (5.2)	<0.001[α]	42.1 (12.0)
Female, n (%)	6474 (61.8)	830 (63)	0.398 [β]	7304 (62)
Races, n (%) [a]				
White	6217 (64.9)	981 (79.8)	<0.001 [β]	7198 (66.6)
Black	1033 (10.8)	76 (6.2)		1109 (10.3)
Hispanic	1479 (15.5)	81 (6.6)		1560 (14.4)
Asian	339 (3.5)	33 (2.7)		372 (3.4)
Native	46 (0.5)	6 (0.5)		52 (0.5)
Others	460 (4.8)	52 (4.2)		512 (4.7)
Median household income quartile for patient zipcode, n (%)				
Lowest	1923 (18.5)	211 (15.3)	<0.001 [β]	2134 (18.1)
Second Lowest	2335 (22.4)	287 (20.8)		2622 (22.3)
Second Highest	2973 (28.6)	362 (26.3)		3335 (28.3)
Highest	3174 (30.5)	517 (37.6)		3691 (31.3)
Insurance Status, n (%)				
Others [b]	4255 (41.7)	552 (40.2)	0.001 [β]	4807 (41.5)
Medicare	1154 (11.3)	202 (14.7)		1356 (11.7)
Medicaid	174 (1.7)	14 (1)		188 (1.6)
Private Insurance	4621 (45.3)	604 (44)		5225 (45.1)
Patient Location, n (%)				
Central counties of metro areas of >=1 million population	3507 (33.7)	420 (30.3)	0.185 [β]	3927 (33.3)
Fringe counties of metro areas of >=1 million population	3006 (28.9)	408 (29.4)		3414 (28.9)
Counties in metro areas of 250,000-999,999 population	1890 (18.1)	265 (19.1)		2155 (18.3)
Counties in metro areas of 50,000-249,999 population	804 (7.7)	117 (8.4)		921 (7.8)
Micropolitan counties	788 (7.6)	113 (8.1)		901 (7.6)
Not metropolitan or micropolitan counties	422 (4.1)	65 (4.7)		487 (4.1)
Hospital control/ownership				
Government, nonfederal	2146 (20.2)	272 (19.4)	0.002 [β]	2418 (20.2)
Private, not-profit	7601 (71.7)	1052 (75.1)		8653 (72.1)
Private, for-profit	854 (8.1)	77 (5.5)		931 (7.8)
Hospital size (based on number of beds)				
Small	391 (3.7)	46 (3.3)	0.359 [β]	437 (3.6)
Medium	1044 (9.9)	153 (10.9)		1197 (10)

Large	9166 (86.5)	1202 (85.8)		10368 (86.4)
Age-adjusted Charlson Comorbidity Index	0.06 (0.28)	0.07 (0.29)	0.067 [α]	0.06 (0.28)
Clavien grade				
Grade 1	810 (7.6)	113 (8.1)	<0.001 [β]	923 (7.7)
Grade 2	395 (3.7)	45 (3.2)		440 (3.7)
Grade 3	298 (2.8)	66 (4.7)		364 (3)
Grade 4	38 (0.4)	15 (1.1)		53 (0.4)
Type of complications				
Genitourinary	96 (0.9)	21 (1.5)	0.033 [β]	117 (1)
Vascular	27 (0.3)	7 (0.5)	0.104 [β]	34 (0.3)
Bleeding	156 (1.5)	31 (2.2)	0.035 [β]	187 (1.6)
Thrombosis	25 (0.2)	5 (0.4)	0.393 [β]	30 (0.3)
Wound	61 (0.6)	11 (0.8)	0.338 [β]	72 (0.6)
Hernia	106 (1)	26 (1.9)	0.004 [β]	132 (1.1)
Injury	69 (0.7)	17 (1.2)	0.019 [β]	86 (0.7)
Infection	134 (1.3)	19 (1.4)	0.77 [β]	153 (1.3)
Cardiac	96 (0.9)	14 (1)	0.727 [β]	110 (0.9)
Respiratory	221 (2.1)	42 (3)	0.028 [β]	263 (2.2)
Gastrointestinal	475 (4.5)	64 (4.6)	0.877 [β]	539 (4.5)
Other complications	377 (3.6)	37 (2.6)	0.079 [β]	414 (3.4)
Diabetes[c]	#	#	#	18 (0.2)
Obesity	453 (4.3)	166 (11.8)	<0.001 [β]	619 (5.2)
Hypertension	157 (1.5)	413 (29.5)	<0.001 [β]	570 (4.7)
N =	**10618 (88.3)**	**1402 (11.7)**		**12020**

Note: [α] Independent sample T-test, [β] Chi-square test, [σ] Mann-Whitney U-test. [a] This variable had 15% missing values. [b] Others group refer to no insurance (self-pay), or other insurances including Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other government programs. [c] This variable was included later in the regression models (where relevant) but was not presented here due to small count (≤10) following requirement by ARHQ-HCUP.

Table 2. Surgical complications (classified by Clavien-Dindo grade)

	Grade 1 [α]				Grade 2 [α]				≥ Grade 3 [α]			
	N (%)	OR	aOR	95%CI	N (%)	OR	aOR	95%CI	N (%)	OR	aOR	95%CI
LKDs type												
Non-marginal LKDs	810 (7.6)	Ref	Ref		435 (4.1)	Ref	Ref		336 (3.2)	Ref	Ref	
Marginal LKDs	113 (8.1)	1.1	1.0	0.8-1.3	55 (3.9)	1.0	1.5*	1.1-2.2	81 (5.8)	1.9***	1.4	1.0-2.0
Age, Mean (SD)	42.1 (12.1)	1.0	1.0	1.0-1.0	41.9 (12.6)	1.0	1.0	1.0-1.0	45.2 (12.0)	1.02***	1.02**	1.00-1.03
Gender												
Male	392 (8.7)	Ref	Ref		172 (3.8)	Ref	Ref		175 (3.9)	Ref	Ref	#
Female	526 (7.2)	0.8**	0.8**	0.7-0.9	317 (4.3)	0.8**	1.1	0.9-1.3	239 (3.3)	0.8	0.8	0.7-1
Income [a]												
Lowest income quartile	153 (7.2)	Ref	Ref		104 (4.9)	Ref	Ref		63 (3)	Ref	Ref	
Second lowest income quartile	214 (8.2)	1.1	1.2	0.9-1.5	113 (4.3)	0.9	1.0	0.8-1.3	99 (3.8)	1.3	1.3	0.9-1.8
Second highest income quartile	252 (7.6)	1.1	1.1	0.9-1.3	118 (3.5)	0.7	0.8	0.6-1.1	116 (3.5)	1.2	1.1	0.8-1.6
Highest income quartile	283 (7.7)	1.1	1.1	0.9-1.3	145 (3.9)	0.8	0.9	0.6-1.3	133 (3.6)	1.2	1.1	0.8-1.5
Insurane												
Other insurance [b]	367 (7.6)	Ref	Ref		137 (2.9)	Ref	Ref		156 (3.3)	Ref	Ref	
Medicare	106 (7.8)	1.0	1.2	0.9-1.5	58 (4.3)	1.5	1.4	0.8-2.5	67 (4.9)	1.6**	1.7**	1.2-2.3
Medicaid	15 (8)	1.1	1.3	0.8-2.2	7 (3.7)	1.3	1.5	0.6-3.8	6 (3.2)	1.0	1.2	0.5-2.8
Private insurance	364 (7)	0.9	1.0	0.8-1.2	286 (5.5)	1.9	1.4	0.9-2.1	174 (3.3)	1.0	1.1	0.8-1.4
Hospital control/ownership												
Government, nonfederal	195 (8.1)	Ref	Ref		69 (2.9)	Ref	Ref		95 (3.9)	Ref	Ref	
Private, not-profit	678 (7.8)	1.0	0.8	0.6-1.1	279 (3.2)	1.2	1.2	0.6-2.3	302 (3.5)	0.9	0.9	0.6-1.2
Private, for-profit	49 (5.3)	0.7	0.7	0.4-1.2	140 (15)	5.7**	8.8***	3.2-24.7	20 (2.2)	0.5*	0.5*	0.3-0.9
Hospital size (based on number of beds)												
Small	20 (4.6)	Ref	Ref		11 (2.5)	Ref	Ref		10 (2.3)	Ref	Ref	
Medium	83 (6.9)	1.6	1.2	0.6-2.5	21 (1.8)	0.6	1.9	0.3-11	45 (3.8)	1.6	2.1	0.6-7.1
Large	819 (7.9)	1.8*	1.3	0.7-2.6	456 (4.4)	1.7	7.8**	1.7-35.9	362 (3.5)	1.5	1.9	0.6-6.2
CCI	0.1 (0.3)	1.6***	1.5***	1.2-1.9	0.1 (0.3)	1.0	1.0	0.7-1.4	0.1 (0.4)	1.3	1.3	1-1.8

Obesity													
	No	855 (7.5)	Ref	Ref		479 (4.2)	Ref	Ref		392 (3.4)	Ref	Ref	
	Yes	68 (11)	1.5**	1.4*	1-1.9	11 (1.8)	0.4*	0.4**	0.2-0.8	25 (4)	1.2	1.1	0.7-1.7
Hypertension													
	No	869 (7.6)	Ref	Ref		476 (4.2)	Ref	Ref		390 (3.4)	Ref	Ref	
	Yes	54 (9.5)	1.2	1.2	0.9-1.7	14 (2.5)	0.6	0.5*	0.3-0.9	27 (4.7)	1.4	0.9	0.6-1.4
	N=			**11097**				**11080**				**11097**	

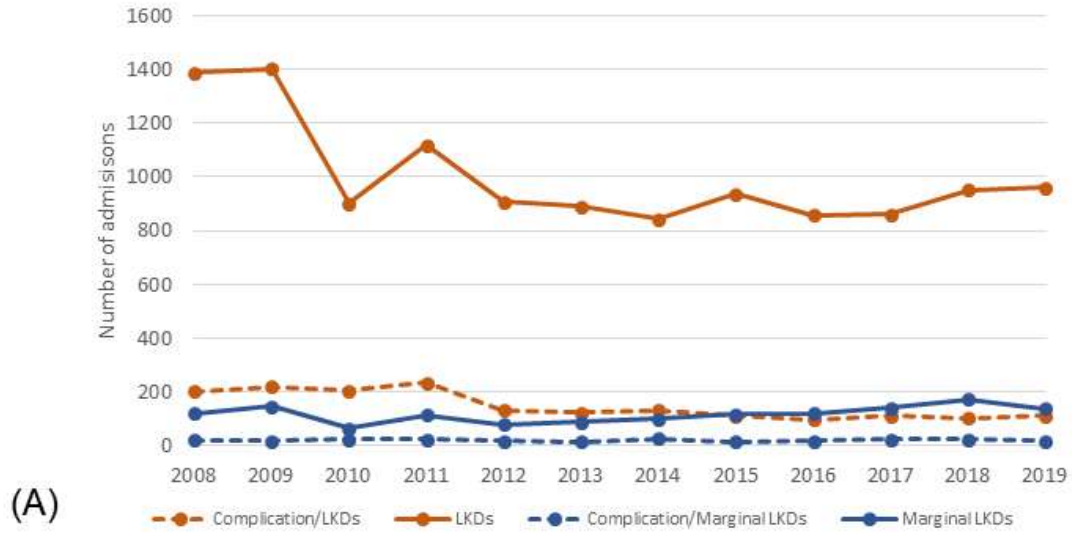
*Note: [α] Multivariable logistic regression model, weighted for the survey design of HCUP NIS data, Diabetes was included as a covariate (where relevant) but not reported here due to small cell count. [a] Income quartiles presented in this table are the estimated median household income of residents in the patient's ZIP Code. [b] Others refer to no insurance (self-pay), or other insurances including Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other government programs. CCI: Deyo-Charlson Comorbidity Index. *p < 0.05, **p < 0.01, ***p < 0.001.*

Table 3. Factors associated with increased/decreased LOS and hospital incurred cost

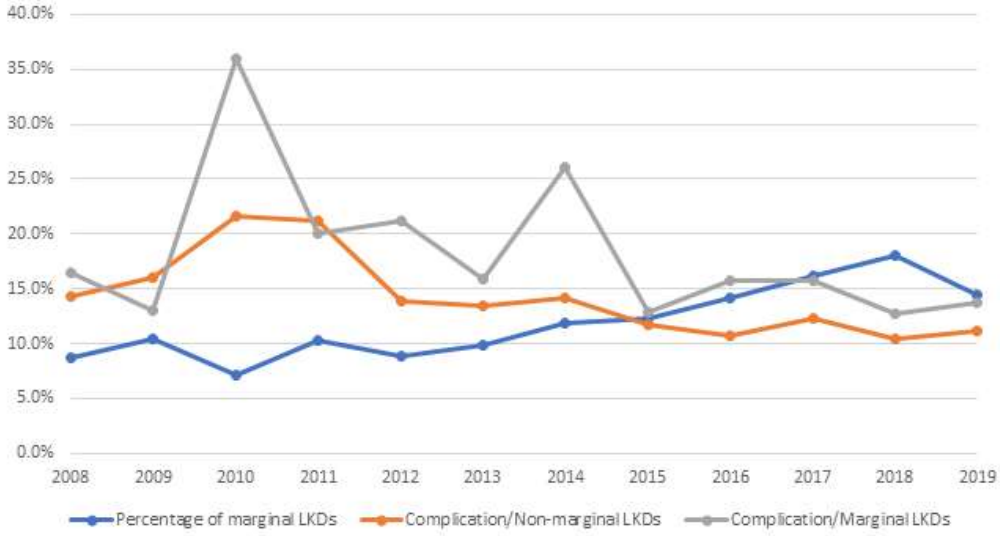
	LOS (days) [α]				Hospital cost ($2019) [β]				N
	Mean (SD)	Unadjusted	Adjusted	95%CI	Mean (SD)	Unadjusted	Adjusted	95%CI	
LKDs type									
Non-marginal LKDs	2.6 (1.2)	Ref	Ref		14202 (5998)	Ref	Ref		10618
Marginal LKDs	2.5 (1.2)	-0.02	-0.09	-0.19 to 0.01	14954 (5944)	755***	37	-460 to 535	1402
Age (years)		0	0	0 to 0		16**	10	-3 to 22	
Gender									
Male	2.6 (1.4)	Ref	Ref		14592 (6439)	Ref	Ref		4485
Female	2.6 (1.2)	0.01	0.04	-0.01 to 0.08	14015 (5665)	-569***	-498***	-746 to -250	7304
Income[a]									
Lowest income quartile	2.6 (1.1)	Ref	Ref		13726 (5147)	Ref	Ref		2134
Second lowest income quartile	2.6 (1.3)	0	-0.01	-0.08 to 0.07	14389 (6013)	641**	546**	212 to 881	2622
Second highest income quartile	2.5 (1.2)	-0.06	-0.06	-0.13 to 0.01	14580 (6251)	835***	693***	347 to 1038	3335
Highest income quartile	2.5 (1.3)	-0.1*	-0.1*	-0.18 to -0.02	14270 (6203)	527*	360	-62 to 782	3691
Insurane									
Other insurance[b]	2.6 (1.2)	Ref	Ref		15000 (5278)	Ref	Ref		4807
Medicare	2.7 (1.3)	0.04	0.03	-0.12 to 0.19	15167 (7755)	221	525	-492 to 1542	1356
Medicaid	2.7 (1)	0.04	0.01	-0.17 to 0.19	17024 (7237)	2215*	1743	-92 to 3578	188
Private insurance	2.4 (1.2)	-0.2*	-0.19*	-0.36 to -0.02	13424 (6044)	-1516***	-1081***	-1867 to -295	5225
Hospital control/ownership									
Government, nonfederal	2.7 (1.2)	Ref	Ref		14311 (5614)	Ref	Ref		2418
Private, not-profit	2.5 (1.2)	-0.13	-0.11	-0.32 to 0.09	14760 (6053)	441	474	-630 to 1579	8653
Private, for-profit	2.4 (1.3)	-0.28	-0.01	-0.31 to 0.3	10076 (4731)	-4196***	-3334***	-5113 to -1555	931
Hospital size (based on number of beds)									

Small	1.9 (0.9)	Ref	Ref		10216 (5272)	Ref	Ref		437
Medium	2.4 (1.1)	0.51	0.51*	0.11 to 0.91	15027 (4789)	4824***	3036***	1349 to 4723	1197
Large	2.6 (1.2)	0.73***	0.71***	0.38 to 1.05	14375 (6093)	4183***	2066*	348 to 3784	10368
CCI		0.33***	0.30***	0.14 to 0.46		813***	685**	242 to 1129	
Diabetes									
No	2.6 (1.2)	Ref	Ref		14290 (5997)	Ref	Ref		12002
Yes	2.5 (0.6)	-0.06	-0.51*	-0.81 to -0.21	13904 (5277)	-410	-1656	-3929 to 617	18
Obesity									
No	2.6 (1.2)	Ref	Ref		14248 (5980)	Ref	Ref		11401
Yes	2.6 (1.1)	-0.02	-0.03	-0.13 to 0.07	15074 (6275)	809*	784**	186 to 1383	619
Hypertension									
No	2.6 (1.2)	Ref	Ref		14248 (5980)	Ref	Ref		11450
Yes	2.6 (1.5)	0.04	0.11	-0.03 to 0.24	15131 (6254)	894**	756*	118 to 1394	570
Surgical complications, Clavien classification									
No complication	2.4 (1)	Ref	Ref		14094 (5640)	Ref	Ref		10240
From grade 1	3.3 (1.8)	0.9***	0.88***	0.74 to 1.01	15412 (7636)	1313**	1525***	903 to 2146	1780
N=			**11097**				**10579**		

*Note: [α] Multivariable linear regression model, weighted for the survey design of HCUP NIS data. [β] Generalized linear regression model, weighted for the survey design of HCUP NIS data. [a] Income quartiles presented in this table are the estimated median household income of residents in the patient's ZIP Code. [b] Others refer to no insurance (self-pay), or other insurances including Worker's Compensation, CHAMPUS, CHAMPVA, Title V, and other government programs. CCI: Deyo-Charlson Comorbidity Index. *p < 0.05, **p < 0.01, ***p < 0.001.*


1600
1400
1200
1000
800
600
400
200
0
Number of admissions
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Complication/LKDs
LKDs
Complication/Marginal LKDs
Marginal LKDs

(A)


40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
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2008
2009
2010
2011
2012
2013
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2015
2016
2017
2018
2019
Percentage of marginal LKDs
Complication/Non-marginal LKDs
Complication/Marginal LKDs

(B)