World J Surg (2019) 43:67–74
https://doi.org/10.1007/s00268-018-4777-5

ORIGINAL SCIENTIFIC REPORT

Clinical Outcomes and Healthcare Costs Associated with Laparoscopic Appendectomy in a Middle-Income Country with Universal Health Coverage

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Published online: 25 August 2018

Abstract

Background Although many studies have compared outcomes of laparoscopic appendectomy (LA) and open appendectomy (OA), some clinical and economic outcomes continue to be controversial, particularly in low–medium-income countries. We aimed at determining clinical and economic outcomes associated with LA versus OA in adult patients in Colombia.

Methods Retrospective, cohort study based on administrative healthcare records included all patients who underwent LA or OA in Colombia's contributory regime between July 1, 2013, and September 30, 2015. Outcomes were 30-day mortality rates, ICU admissions rates, length of stay (LOS), and hospital costs provided until discharge. Propensity score matching techniques were used to balance the baseline characteristics of patients (age, sex, comorbidities based on the Charlson index, insurer, and geographic location) and to estimate the average treatment effect (ATE) of LA as compared to OA over outcomes.

Results A total of 65,625 subjects were included, 92.9% underwent OA and 7.1% LA. For the entire population, 30-day mortality was 0.74 per 100 appendectomies (95% CI 0.67–0.81), the mean and median LOS were 3.83 days and 1 day, respectively, and the ICU admissions rate during the first 30 days was 7.92% (95% CI 7.71–8.12). The ATE shows an absolute difference in the mortality rate after 30 days of −0.35 per 100 appendectomies ($p = 0.023$), in favor of LA. No effects on ICU admissions or LOS were identified. LA was found to increase costs by 514.13 USD on average, with total costs of 772.78 USD for OA and 1286.91 USD for LA ($p < 0.001$).

Conclusions In Colombia's contributory regime, LA is associated with lower 30-day mortality rate and higher hospital costs as compared to OA. No differences are found in ICU admissions or LOS.

Introduction

Acute appendicitis is the most common cause of acute abdominal surgeries [1]. The risk of developing appendicitis in one's lifetime is 8.6% for men and 6.7% for women [2, 3], and the disease is associated with significant morbidity and mortality, especially in low–medium-income countries (LMIC) [4]. This is explained by close relationship between adverse outcomes and ability to obtain timely and adequate surgical treatment, which is scarce in these types of countries. In addition, due to high frequency of appendicitis and potential outcomes

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associated with it, this condition greatly impacts the consumption of healthcare services and the costs of medical care [5].

Two surgical techniques are used for appendicitis: laparoscopic appendectomy (LA) and open appendectomy (OA). Although both techniques are effective and safe, studies continue to investigate how to determine which procedure is more suitable, by evaluating clinical outcomes, cost of services, results obtained in different contexts (i.e., health systems and countries), differences among particular patient groups, and usefulness in different clinical stages of disease [6]. Several studies performed in high-income countries suggest that LA is a safe procedure resulting in less morbidity than OA, in terms of a lower rate of complications during recovery (except for intra-abdominal abscesses), shorter hospital stays, less postoperative pain, and returning sooner to daily activities [7–10]. Randomized clinical trials have not conclusively determined differences in mortality or costs [6, 11], so it is important to use real-world evidence with sample sizes that are large enough to provide more information.

On the other hand, little information exists about the outcomes associated with appendectomies in LMIC, resulting in a lack of knowledge in these countries about both crude incidence of events related to these surgeries and comparative results (effectiveness, safety, and costs) between the two techniques (LA and OA). The Lancet Commission has called for monitoring and disseminating the outcomes associated with surgeries, as well as studying the issue of access to timely and quality surgical services in LMIC [12].

Colombia is a middle-income country with universal health coverage (97% of the total population of 47,661,787 inhabitants in the year 2014). Health care is provided by a health system that is based on mandatory insurance, which offers a comprehensive benefits plan covering both LA and OA. The two insurance regimes are contributory (48%), which is composed of citizens with incomes above the legal minimum wage, and subsidized (51%), composed of citizens whose incomes are below the current monthly minimum wage [13]. Although Colombia's health system was established in 1993, no national representative studies have been performed that describe clinical outcomes and costs associated with surgeries (including appendectomies). We aimed determine clinical and economic outcomes associated with appendectomies and compare outcomes of LA versus OA in the population of adult patients who belong to Colombia's contributory regime.

Methods

Type of study and context

This was a retrospective, cohort study based on administrative health records for all patients older than 18 years old belonging to contributory regime in Colombia and who underwent an appendectomy between June 1, 2013, and September 30, 2015. Using information collected from many official sources of information by Integrated Social Security Information System (in Spanish, *Sistema Integrado de Información de Protección Social* [SISPRO]), this study obtained information about all the healthcare services consumed by patients belonging to the contributory regime and reported by the insurers (Health Promoter Enterprises [EPS]) for the years 2013, 2014, and 2015. This information serves as basis for calculating EPS premiums established for each individual in the system. Two cohorts were formed according to appendectomy codes: (1) exposed cohort composed of individuals who underwent an LA and (2) unexposed cohort made up of individuals who underwent an OA.

Variables

The main exposure variable was a type of appendectomy. The main clinical outcome was 30-day mortality, which was obtained from death certificates reported in vital statistics provided by SISPRO. Additional outcome variables included: length of stay (LOS), intensive care unit (ICU) admissions up to 30 days, and hospital costs. The costs of healthcare services provided were determined from a third-party payer perspective and included all of the services provided until discharge and for which EPS paid to hospitals where appendectomies were performed. These costs are reported in US dollars (USD) for the year 2014. Lastly, individual baseline characteristics identified included sociodemographic variables (age, sex, city, department, EPS) and comorbidities prior to appendectomy (we used recommendations by Sundararajan et al. [14] to identify all the comorbidities proposed in Charlson index).

Analysis

Descriptive statistics were used to describe and compare sociodemographic and clinical characteristic for entire population and for each cohort. In order to decrease possible selection bias due to lack of randomization, associations between type of appendectomy and outcomes of interest were identified with matching techniques. The average treatment effect (ATE) (i.e., absolute risk difference) resulting from matching analysis was estimated according to recommendations by Austin [15, 16]. First, baseline characteristics of both cohorts were compared based on statistical differences in their distribution and standardized differences. Second, a multivariate logit model was generated in order to predict the probability of being exposed to LA as a function of baseline characteristics prior to surgery. This model included known variables reported in the literature as well as possible confounders and/or predictors of exposure, specifically characteristics that presented statistical differences in the first step (age, sex, EPS, geographic location, and Charlson index). Third, different matching methods were used to balance baseline characteristics, including: propensity score matching (PSM) [17], nearest-neighbor matching (NNM) [18, 19], and inverse probability weighting (IPW) [20, 21]. The method resulting in best balance was selected, which was defined as standardized differences under 0.1 for all the baseline variables [16]. Lastly, ATE was identified for each of the outcomes of interest and 95% confidence intervals were estimated based on robust standard errors [15, 21]. A logarithmic transformation was performed for cost outcome. All of these analyses were conducted with Stata 15®. This study was approved by Institutional Review Board of National University of Colombia's School of Medicine.

Results

Descriptive

A total of 65,625 subjects were included. Among them, 60,959 (92.9%) underwent OA and 4630 (7.1%) underwent LA. Table 1 presents baseline characteristics for entire population and for each cohort. Differences were found in females, prevalence of congestive heart failure, connective tissue disease, diabetes, and renal disease, all of which represented statistical differences according to the Charlson index. All the patients were treated in hospitals located in any city in Colombia. In addition, differences in use of LA were found among regions and EPS. For example, Bogota performed 70.57% of LA and 31.29% of OA, and EPS 6 performed 28.16% of LA and 7.18% of OA. All of these findings indicate an imbalance in baseline characteristics between cohorts, which due to possible selection bias.

Matching

PSM was the best technique for balancing baseline characteristics, which resulted in standardized differences below or very near 0.1 for all of the baseline variables. Table 2 presents the balance in baseline characteristics for the two cohorts before and after matching process. It was found that PSM matching process resulted in a highly balanced sample in terms of sociodemographic characteristics, comorbidities, EPS, and Department where surgery was provided. Only age, EPS 12, and the Departments of Caldas and Norte de Santander had standardized differences over 0.1 (0.11, 0.13, 0.19 and 0.12, respectively). Nevertheless, none of these differences were over 0.2, which would represent a critical imbalance. It was found that the matching process generated a pseudo-population with an identical number of exposed and unexposed individuals.

Clinical outcomes

The 30-day crude mortality rate associated with appendectomies was 0.74 per 100 appendectomies (95% CI 0.67–0.81) for the entire study population. The ATE (i.e., absolute difference in the mortality rate) resulting from PSM showed that being treated with LA decreased the probability of dying within 30 days of surgery by 0.35 per 100 appendectomies ($p = 0.023$), with a 30-day mortality of 0.75 per 100 appendectomies for subjects undergoing OA versus 0.40 per 100 appendectomies for the LA group (Table 3). The mean LOS for all the patients in the study was 3.83 days (SD 8.68), the median LOS was 1 day (p25th: 1–p75th: 1), and the proportion of patients admitted to ICU during the first 30 days was 7.92% (95% CI 7.71–8.12). In terms of ICU admissions and LOS, PSM analysis did not find any differences between LA and OA.

Healthcare costs

The median total cost was 666.37 USD (p25th: 447.90–p75th: 1235.78). Figure 1 shows the cost distributions for LA and OA groups, by geographic region and EPS. As can be seen, costs varied greatly by region and by EPS. While the costs associated with hospital services other than surgery were less for LA than for OA (median cost 214.92 USD vs 223.61 USD, respectively), total hospital costs associated with LA appear to be higher. This is primarily due to the cost associated with the surgical procedure (median cost 605.80 USD vs 342.21 USD, respectively). ATE estimator indicates that belonging to LA cohort increases the cost logarithm by 0.50 ($p = 0.00$) (Table 3), which corresponds to a mean higher cost of 514.13 USD, with hospital costs of 772.78 USD for the OA group and 1286.91 USD for the LA group.

Discussion

There is a good deal of experimental and observational evidence that compares clinical and economic outcomes associated with LA and OA, which shows some advantages

Table 1 Baseline characteristics of full sample and by cohorts

	Full sample	Appendectomy		
	n = 65,589	Open n = 60,959	Laparoscopic n = 4630	p value
Age Me (p25–p75)	32.1 (24.7–44.4)	32.1 (24.7–44.4)	32.4 (24.7–44.6)	0.23
Female n (%)	32,698 (49.8)	29,940 (49.0)	2758 (59.5)	< 0.001[a]
Comorbidities n (%)				
Acute myocardial infarction	258 (0.39)	240 (0.39)	18 (0.39)	0.96[a]
Congestive heart failure	496 (0.76)	477 (0.78)	19 (0.41)	0.005[a]
Peripheral vascular disease	101 (0.15)	94 (0.15)	7 (0.15)	0.96[a]
Cerebral vascular accident	538 (0.82)	511 (0.84)	27 (0.58)	0.064[a]
Dementia	89 (0.14)	84 (0.14)	5 (0.11)	0.59[a]
Pulmonary disease	2009 (3.06)	1879 (3.08)	130 (2.81)	0.29[a]
Connective tissue disorder	742 (1.13)	672 (1.1)	70 (1.51)	0.011[a]
Peptic ulcer	201 (0.31)	195 (0.32)	6 (0.13)	0.019[b]
Liver disease	50 (0.08)	43 (0.07)	7 (0.15)	0.086[b]
Diabetes	2073 (3.16)	1958 (3.21)	115 (2.48)	0.006[a]
Diabetes complications	208 (0.32)	193 (0.32)	15 (0.32)	0.93[a]
Paraplegia	37 (0.06)	37 (0.06)	0 (0)	0.11[b]
Renal disease	1073 (1.64)	1026 (1.68)	47 (1.01)	0.001[a]
Cancer	1570 (2.39)	1451 (2.38)	119 (2.57)	0.41[a]
Metastatic cancer	160 (0.24)	151 (0.25)	9 (0.19)	0.64[b]
Severe liver disease	13 (0.02)	13 (0.02)	0 (0)	1[b]
HIV	260 (0.4)	235 (0.39)	25 (0.54)	0.1[a]
Charlson index > 0 n (%)	7494 (11.4)	7002 (11.4)	492 (10.6)	0.06[c]

Me, median; p25, percentile25th; p75, percentile75th

[a] χ^2

[b] Fisher exact

[c] Mann–Whitney

of LA in terms of certain clinical outcomes or sceneries [7, 9, 22]. Nevertheless, questions still remain about the usefulness of LA with respect to 30-day mortality, associated costs, and performance in real-world scenarios [6, 11]. This is the first study in Latin America to compare clinical and economic outcomes associated with LA and OA using a nationally representative sample. The study was conducted in Colombia, a middle-income country with a mandatory universal coverage health system, with a sample representative of population with higher incomes. It shows large differences in outcomes among the geographic regions and health insurers. This study performed a causal inference analysis using PSM, making it possible to reduce the effects of selection bias, which is inherent in observation studies [23].

The 30-day mortality rate for the entire study population was 0.74 per 100 patients undergoing an appendectomy. This is the recommended indicator for describing perioperative mortality rates [24–26]. Additionally, this is the first report of mortality rates associated with appendectomies in Colombia, and it adheres to recommendations by the Lancet Commission for monitoring and reporting of core surgical indicators in all countries worldwide [12]. This 30-day mortality rate for Colombia is higher than that of developed countries. Kotaluoto et al. [27] reported 30-day mortality rates of 0.21 per 100 surgeries for Finland, and Sartelli et al. [28] reported an intra-hospital mortality rate of 0.28 per 100 surgeries for 44 countries. Meanwhile, in our study, the 30-day morality rate per region ranged from 0.38 for Bogota to 1.47 per 100 surgeries for the Pacific region. These results suggest large geographic differences, which may be associated with specific regions, and should be studied by future investigations.

Moreover, regarding the OA–LA comparison, few experiments have evaluated 30-day mortality as a primary outcome, most likely due to its low incidence and the need for large sample sizes. Only one meta-analysis found seven randomized clinical trials that included mortality as a primary outcome, which did not find significant differences between the two techniques (OR 0.97 95% CI 0.29–3.25)

Table 2 Standardized differences of baselines characteristics before and after propensity score matching

	Standardized differences	
	Raw	Weighted
Female	0.211	−0.090
Age	0.007	0.114
Complicated appendectomy	−0.811	−0.040
Charlson index	−0.023	−0.029
EPS number		
1	−0.125	−0.060
2	0.018	−0.009
3	−0.089	0.091
4	0.571	−0.034
5	−0.125	−0.036
6	0.001	−0.039
7	−0.282	−0.025
8	−0.141	0.059
9	0.156	−0.080
10	−0.044	0.002
11	0.011	−0.017
12	−0.159	0.136
Department		
Atlántico	−0.265	−0.089
Bogotá	0.852	−0.086
Bolívar	−0.129	−0.075
Boyacá	−0.197	0.006
Caldas	−0.106	0.198
Caquetá	−0.064	−0.050
Cauca	0.029	0.076
Cesar	−0.181	0.068
Córdoba	−0.139	−0.048
Cundinamarca	−0.043	0.031
Choco	−0.022	0.023
Huila	−0.160	−0.039
La Guajira	−0.101	−0.047
Magdalena	−0.101	−0.025
Meta	−0.211	−0.025
Nariño	−0.080	−0.012
N de Santander	−0.046	0.124
Quindío	0.028	0.001
Risaralda	−0.094	−0.007
Santander	−0.297	0.056
Sucre	−0.117	−0.074
Tolima	−0.205	0.054
Valle del Cauca	0.080	−0.048
Arauca	−0.066	0.019
Casanare	−0.146	−0.077
Putumayo	−0.063	−0.009
Amazonas	−0.010	−0.017
Guainía	−0.013	0.015
Vichada	−0.007	0.006
Exposed observations	4630	65,417
Non-exposed observations	60,787	65,417
Total observations	65,417	130,834

[11]. Our study found that the absolute difference in the mortality rate during the first 30 postoperative days was 0.35 per 100 appendectomies less for patients undergoing LA than for those undergoing OA. This absolute risk difference is equivalent to a relative risk reduction of 47%, which we consider an impressive result in favor of LA. No differences were found in ICU admissions rates or mean LOS.

Another outcome of interest that contributes to the body of evidence comparing LA and OA is hospital costs corresponding to each of these techniques. Current evidence indicates that LA is associated with higher costs due to longer surgeries and the need for more technology and trained staff, while it lowers costs due to decreased surgical site infections and shorter hospital stays and recovery times [29–31]. There is no conclusive information regarding which technique costs less. That depends on the context in which techniques are evaluated (type of health system, controlled trial, real-world evidence, etc.), healthcare services included (hospital, surgical procedure, complications, rehospitalizations, etc.), and perspective used (third-party payer or social). Although some studies have reported that costs associated with LA are generally higher [29, 32], cost-effectiveness studies indicate that LA is cost-effective for certain outcomes, as well as for particular cost-effectiveness thresholds and specific scenarios [33, 34]. This has been demonstrated by randomized trials and real-world evidence, including a study performed in Colombia [35]. Costs analyzed by our study represent net expenditure incurred by EPS for health care related to hospital services, which includes surgery and all of the services provided until discharge. Although it finds higher LA costs compared with OA (514 USD more in 2014), some of costs that could modify these results were not included, such as those associated with rehospitalizations and reinterventions occurring after discharge from hospital, and costs associated with a social perspective. More detailed analyses are needed to determine economic cost of LA in Colombia.

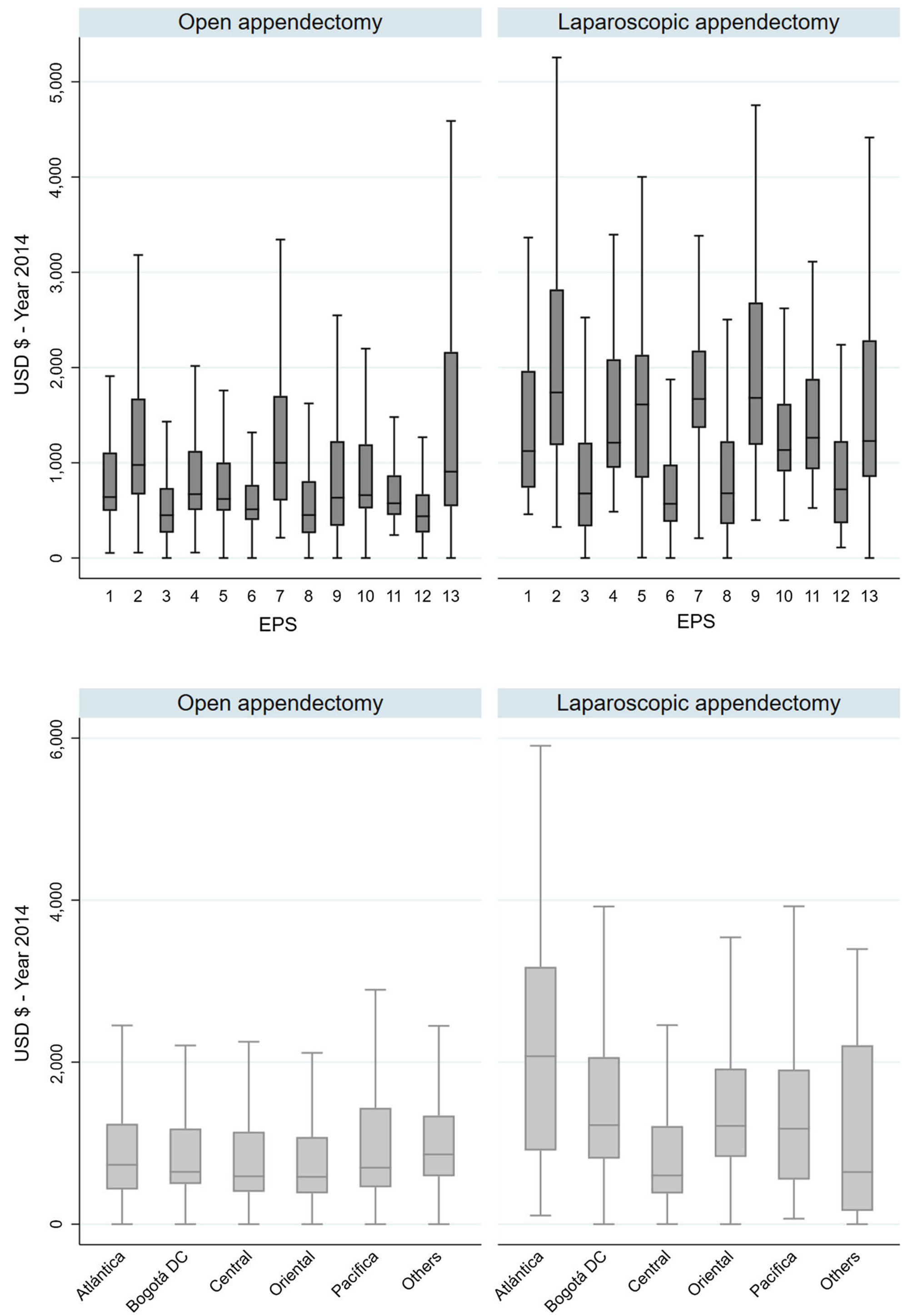
In spite of having a health system with universal coverage and a comprehensive benefits plan that provides the same coverage for all members, analysis by region and by insurer shows large differences in both associated mortality and costs incurred. This suggests that the theoretical

Table 3 Laparoscopic appendectomy's average treatment effect over clinical outcomes and healthcare costs with PSM

Laparoscopic appendectomy	30-day mortality (%)	ICU (%)	LOS (days)	Costs (log USD$)
ATE [95% CI]	−0.35** [−0.65 to −0.05]	2.15 [−1.21 to 5.51]	0.21 [−1.01 to 1.42]	0.50*** [0.30–0.70]
Observations	65,417	65,417	65,417	65,274

CI confidence interval, *ICU* intensive care unit, *LOS* length of stay, *ATE* average treatment effect, *Log USD$* logarithm of US dollars for 2014
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Fig. 1 Cost distributions between OA and LA by EPS and geographical region



equality in regulation does not effectively translate into clinical practice in terms of clinical outcomes in specific geographic regions or by particular insurers. Several publications have reported on delayed access to safe and effective surgical procedures and its relationship to clinical outcomes [36]. This lack of access is not uniform, with differences existing among countries as well as within the same country, regardless of the nation's wealth [37, 38]. This inequality can be seen in some countries whose healthcare systems are segmented by sector. A study conducted in the city of Cabo, South Africa, reported large differences in clinical outcomes for patients undergoing appendectomies in public sector, who presented higher rupture rates, more serious complications, longer hospital stays, and longer recovery times than patients in private sector [39]. A more recent study, which included patients from rural and urban areas in Rochester (USA) and Pietermaritzburg (South Africa), found that regardless of the country, patients in rural regions tended to have more serious illnesses needing more invasive surgical treatment, and thus, they had longer hospital stays, higher mortality, and a higher rate of complications, which were more serious [40].

This study may have some weaknesses, and therefore results should be interpreted with caution. First, because of its retrospective and observational nature, there is a high probability of information and selection bias. With regard to information bias, database used is highly standardized, since it serves as the basis for calculating the system's premiums. Therefore, the insurers have incentives to report all of the services for which they paid. In addition, the information related to costs was essentially what the health system paid for its members. With regard to selection bias, this was mitigated by matching analysis, with which comparable samples can be obtained based on observable information, thereby simulating a randomized experiment. On the other hand, a lack of relevant clinical information not identified by administrative records can produce non-measure confounding, for example, illness severity. Several studies report that this variable affects mortality and other clinical outcomes (surgical site infection, readmissions, LOS, etc.) [27, 41, 42]. Therefore, in order to decrease effects of this lack of information, our analysis included an additional variable that represented surgical codes associated with appendectomies with peritonitis drainage. This variable showed a large imbalance in unmatched sample (toward OA), but it was corrected using PSM, which suggests adequate control of this possible confounding factor. All of the above does not diminish relevance of this study's findings.

In conclusion, the findings of this study allow to indicate that in Colombia's contributory regime, LA is associated with lower 30-day mortality rate and higher hospital costs as compared to OA.

Acknowledgements The authors thank Office of Information and Communication Technology of Ministry of Health and Social Protection from Colombia (Dolly Ovalle and Luz Emilse Rincon), for providing anonymized data for this study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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