ORIGINAL ARTICLE

Estimation of the standard surgical times of the most common general surgery procedures and the probability of extending them to make surgery scheduling more efficient

Manuel David Pérez Ruiz* [1,a]; Luis Bernardo Enríquez-Sánchez [1,a]; Carolina Martínez Loya [2,b]; Miguel Eduardo Pacheco Pérez [2,b]; Estefanía Garfio Mandujano [2,b]; Jacqueline Rodríguez Rodríguez [2,b]; Myriam Ramos Segovia [2,b]; Carlos Eduardo Quiñones Gutiérrez [2,b]

ABSTRACT

Objective: To determine the standard surgical times of the four most common general surgery procedures (unilateral inguinal hernioplasty, bilateral inguinal hernioplasty, umbilical hernioplasty and cholecystectomy) in a second-level hospital and to estimate the probability of extending the time of each of the procedures. Efficiency is a widely studied subject in economics. It involves the need for fewer elements in the production of a certain level of goods and services. Therefore, it is extremely important to consider it in the field of surgery.
Materials and methods: An observational, descriptive and retrospective study. It used the operating room records from 2017 to 2019 of the General Surgery service in a second-level hospital. Based on this information, the time required for each procedure was standardized using the mean for each one (umbilical hernioplasty, unilateral or bilateral inguinal hernioplasty and cholecystectomy). The probability of extending surgical times was estimated based on the obtained data and confidence interval.
Results: The mean for unilateral inguinal hernioplasty was 76 min (95.00 % CI: 72-80 min, *SD* 23), for bilateral inguinal hernioplasty 104.38 min (95.00 % CI: 91-116 min, *SD* 41.7), for umbilical hernioplasty 59.31 min (95.00 % CI: 54-63 min, *SD* 29.99) and for cholecystectomy 85.735 min (95.00 % CI: 83-88 min). The probability of scheduling three surgical interventions and completing all of them on time (upper limit of the CI) is 92.69 %, and the probability of scheduling three surgical interventions and extending the time of all of them is 0.0016 % (lower limit of the CI).
Conclusions: Planning scheduled operations using standardized surgical times is feasible. Updated statistics on surgical procedures (average time for each procedure) are required since it is possible to more accurately detect and supervise operating room dynamics by identifying opportunity areas. This will make operating room time more efficient for the benefit of health care systems and patients.

Keywords: Efficiency; Operating Rooms; Probability; Planning (Source: MeSH NLM).

INTRODUCTION

In 2015, the World Bank estimated that 1,303 surgical procedures per 100,000 inhabitants were performed in Mexico [(1)]. In 2010, there were 3,976 hospital units in the country, two-thirds of which were private units; in the public sector, the largest number of hospitals is under the control of the Ministry of Health, and in the same year, there were 2,900 ORs (operating rooms) [(2)]. According to data from the Instituto Mexicano de Seguridad Social (IMSS - Mexican Social Security Institute), cholecystectomies, hernioplasties and appendectomies are the most common general surgeries [(3)]. In a retrospective study using OR records for four years, 25,114 surgeries were performed, with an annual average of 5,527 and a daily average of 16 procedures. Moreover, it was found that a large part of the OR resources was allocated to obstetric care, chronic conditions (cataracts and endoscopies), accident-related care, and acute abdominal conditions such as appendicitis and cholecystitis [(4)].

Efficiency has been widely studied in the economic field and refers to the need for fewer factors to produce a certain level of goods and services. Therefore, it is crucial to include it in the field of surgery. The OR is the financial hub of the modern hospital, accounting for up to 40 % of a hospital's costs and between 60 % and 70 % of revenue [(5)]. Macario et al. have proposed eight indicators to assess efficiency in surgery: personnel cost overrun, delay in surgery start times, cancellation rate, delay in admission to the recovery

1 Hospital Central del Estado de Chihuahua, Departamento de Cirugía (Surgery Department). Chihuahua, Chihuahua, Mexico.
2 Universidad Autónoma de Chihuahua, Departamento de Investigación (Research Department). Chihuahua, Chihuahua, Mexico.
[a] General surgeon; [b] Medical intern in social service.
*Corresponding author.

area, OR hourly cost margin, rotation and turnover time, prediction bias and prolonged turnover [6]. In Mexico, the Ministry of Health sets its indicators, including surgeries per OR, deferred surgeries and waiting times for surgery [7]. The percentage of hernioplasties performed on the same day is also part of a set of indicators, ("day-case rate," which provide information about the efficiency of the services by identifying their capacity to address ambulatory surgical conditions in a single day [2].

Considering the type of operation (Current Procedural Terminology, CPT) and the hospital, procedure times may vary according to the surgeon. Particularly in the case of complex operations, factors such as the surgeon's relevant experience in work pacing and the composition of the surgical team may have significant effects. It is inferred that the surgical team size has an impact on procedure time: when the team size was increased, the procedure time was extended regardless of other factors such as surgical complexity [8]. The effect of the team composition rises up to 20.00 % and, when combined with the work pace, the overall effect rises up to 30.00 %. Other relevant factors include the age of the surgeon and the time of day. Gender almost never has any effect [9].

Disturbances in surgical schedules resulting from inaccurate estimates of surgery duration create unreliable results. Estimation errors not only affect the flow of patients through the OR but also the coordination of activities in those areas and throughout the care giving process. Surgery-supporting activities that are affected by errors in estimates of surgery time may include, e.g., the rotation of surgical staff or the preparation and delivery of tools and materials. Other disruptions include changes to activities performed by other units, such as pre- and postoperative activities in ward units [10].

A factor that also influences the optimization of surgical services is the surgical waiting list (SWL), the existence of which indicates a mismatch between supply and demand, with a relative excess of the latter. The SWL varies depending on the institution and provides insight into the efficiency and performance of the surgical activity of the evaluated hospital (available OR time vs. utilized OR time), with the firm intention of detecting the causes of delay in healthcare delivery.

Standard surgical times are one of the few ongoing initiatives to measure and improve the efficiency of surgical activity. The surgical intervention time is defined as the time required for an expert surgical team to perform the intervention, measured from the time the patient enters the OR until they leave [11]. Time spent preparing the OR for the next surgery is considered downtime.

The process began with the analysis of the patients included in the SWL of the Madrilenian Health Service, to whom a code was assigned based on the International Classification of Diseases, 9th revision (ICD-9). This method was used to collect data on the most common surgical procedures and to classify all patients on the SWL, assigning a downtime, i.e., the time each group takes to start the next procedure [12].

The Timing in Acute Care Surgery (TACS) classification was previously published to introduce a new tool to triage the timely and appropriate access of emergency general surgery patients to the OR. However, the clinical and operative effectiveness of the TACS classification has not been investigated in subsequent validation studies [13].

Currently, there is a management issue in the surgical area of most hospitals. Surgical procedures are time-consuming in the pre-, intra-, and postsurgical stages. During these processes, different healthcare workers are involved; nevertheless, each hospital or surgeon has different times for each procedure, involving significant variations in each surgical intervention. These variations may result in the cancellation of elective surgeries due to lack of time and delay in rescheduling, which, in turn, increases the SWL and potential complications from surgically managed conditions. It has been comprehensively demonstrated that prolonged operative time can increase the probability of developing a surgical site infection (SSI) in a wide range of surgical procedures and specialties if it exceeds the usual average by 30 min [14]. Some hospitals have specialized equipment in certain ORs, but not in all, which leads to limitations in scheduling. If ORs with specialized equipment are not used for routine cases, then the issue of rescheduling cases can be divided into two separate issues. However, when the rooms with specialized equipment are also usually used for cases that do not require such equipment, the issue of rescheduling cases remains a challenge [15].

The purpose of the study was to determine the mean times of the four most common procedures in general surgery and to estimate the probability of extension for each of them in order to optimize operating room scheduling.

MATERIALS AND METHODS

Study design and population

This was an observational, descriptive, and retrospective study. The records of the most frequently requested surgical procedures between 2017 and 2019 in the General Surgery service of a second-level hospital were accessed. The time required for each procedure was standardized based on this information. The study population included patients who underwent umbilical hernioplasty, unilateral or bilateral inguinal hernioplasty and cholecystectomy during the aforementioned period. Patients who underwent any other procedure were excluded.

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Surgical times collected from the surgical scheduling logbooks were analyzed (start time of anesthetic procedure, start of surgical procedure, end of surgical procedure and end of anesthesia). A separate analysis was performed to obtain the standardized data of the following procedures: umbilical hernioplasty, unilateral inguinal hernioplasty, bilateral inguinal hernioplasty and cholecystectomy.

Data were collected for a three-year period (2017-2019), with a total of 4,050 surgeries performed in 2017, 2,995 surgeries in 2018, and 2,981 surgeries in 2019. From this database, a sample made up of 186 umbilical hernioplasties, 134 unilateral inguinal hernioplasties, 45 bilateral inguinal hernioplasties and 838 cholecystectomies was selected. The names of the surgeons, their times for each surgical procedure and comparison with those of other physicians were recorded.

Variables and measurements

A descriptive analysis of all nominal variables was performed, and then the continuous variable (time) was compared with the nominal variable (surgeon) using hypothesis testing (Student's *t*-test). Significant differences in procedure duration were sought, the mean was identified and, with a 95 % confidence level, surgeons at the extremes of the Gaussian bell curve were identified. Similarly, the times of the most frequently performed surgeries (hernioplasty and cholecystectomy) were standardized.

Statistical analysis

The obtained data were used to conduct a probability analysis in order to calculate the probability of each surgical procedure, in the event of extension or shortening in time, taking confidence intervals into account.

Ethical considerations

This study was conducted as retrospective research, meaning that no real-time patient data were used, and no direct interventions were performed on individuals. Instead, previously recorded data available from public sources and medical record archives were collected and analyzed without identifying the patients involved. It is important to emphasize that this study did not involve interventions on human subjects, obtaining informed consent from patients, or retrospective data collection. Instead, it was based on the review of existing, publicly available data, which allowed research questions to be addressed without jeopardizing the integrity and well-being of patients.

RESULTS

Total surgical time (min) for unilateral inguinal hernioplasty

The analysis revealed that the average time (min) that a surgeon takes to perform a unilateral inguinal hernioplasty was 76 min (95.00 % CI: 72-80 min, *SD* 23) (Figure 1).

Sixteen surgeons were included. According to the total number of surgeries selected, the mean procedure time was obtained and compared with that of the other surgeons (Table 1). Each result was evaluated, and it was identified that Physician No. 8 (mean = 58 min, $p = 0.007$) and Physician No. 16 (mean = 59 min, $p = 0.008$) performed the procedure in a significantly shorter time than the other surgeons.

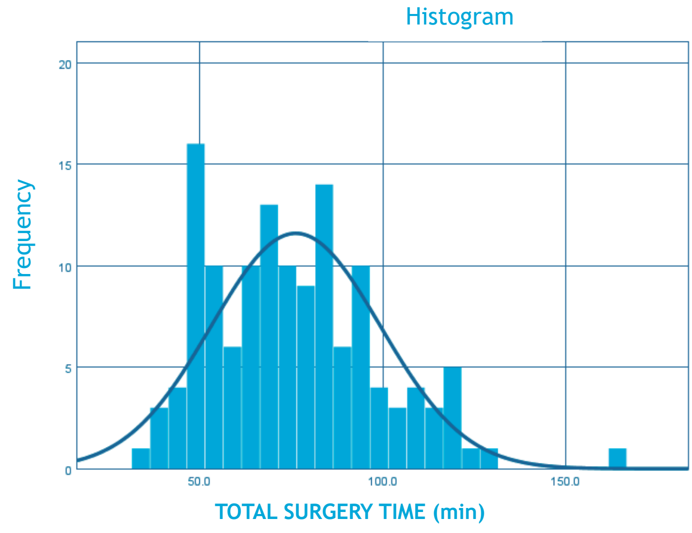

Figure 1. Histogram of total surgery time for unilateral inguinal hernioplasty

Table 1. Comparative table of surgical times for unilateral inguinal hernia by each surgeon

Surgeon	Mean	Standard deviation	*P*
P. 1	64.25	15.27	0.132
Compared to the others	77.01	23.45	
P. 3	76.5	9.19	0.987
Compared to the others	76.23	23.36	
P. 4	62.5	17.67	0.401
Compared to the others	76.45	23.26	
P. 5	87.85	21.01	0.047
Compared to the others	74.86	23.14	
P. 6	57.11	14.26	0.01
Compared to the others	77.64	23.14	
P. 7	68.18	23.14	0.23
Compared to the others	76.97	23.16	
P. 8	58.36	13.32	0.007
Compared to the others	77.86	23.25	
P. 9	75.74	21.67	0.9
Compared to the others	76.37	23.67	
P. 10	93.75	24.62	0.126
Compared to the others	75.69	23.04	
P. 12	75	7.07	0.94
Compared to the others	76.26	23.37	
P. 13	84.6	19.32	0.237
Compared to the others	75.55	23.42	
P. 14	84.42	21.27	0.339
Compared to the others	75.78	23.29	
P. 15	82.92	31.43	0.276
Compared to the others	75.51	22.17	
P. 16	59.33	17.44	0.008
Compared to the others	77.93	23.07	
P. 17	86.5	16.94	0.371
Compared to the others	75.92	23.34	

(P. = Physician)

Total surgical time (min) for bilateral inguinal hernioplasty

The analysis of the time spent in the selected surgeries of bilateral inguinal hernioplasty revealed that the mean time (min) of its completion was 104.38 min (95.00 % CI: 91-116 min, *SD* 41.7) (Figure 2).

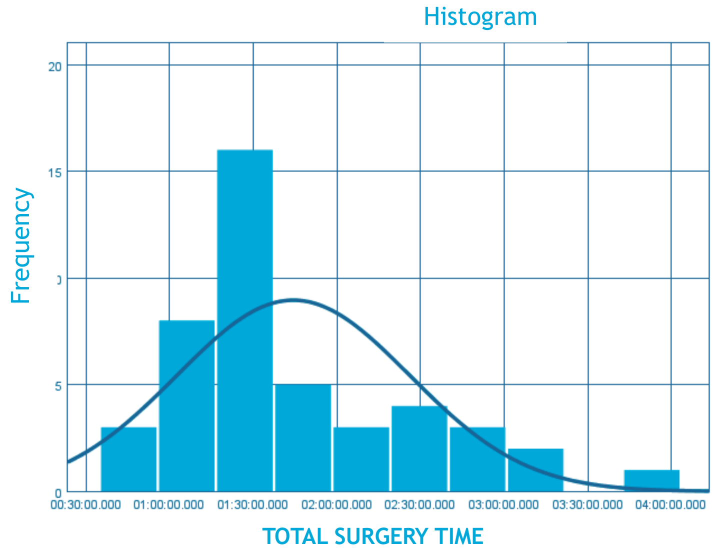

Figure 2. Histogram of total surgical procedure time for bilateral inguinal hernioplasty

According to the database, the minimum surgical time for bilateral inguinal hernioplasty was 34 min, and the maximum time was 240 min.

Regarding the overall view, eight physicians were selected, and their procedures were timed (Table 2). After calculating the average surgical times, Physician No. 1 (mean = 70 min, p = 0.084) and Physician No. 8 (mean = 78 min, p = 0.017) were found to operate in a significantly shorter time than the other surgeons. In contrast, Physician No. 9 (mean = 193 min, p = 0.000) performed the procedure in a significantly longer time compared to the other surgeons.

Table 2. Comparative table of surgical procedure times for bilateral inguinal hernioplasty by each surgeon

Surgeon	Mean	Standard deviation	*P*
P. 1	70	29.72	0.084
Compared to the others	107.73	41.46	
P. 5	97.5	3.53	0.815
Compared to the others	104.69	42.67	
P. 6	91	27.82	0.508
Compared to the others	105.68	42.86	
P. 7	110.3	36.12	0.616
Compared to the others	102.68	43.52	
P. 8	78.72	17.18	0.017
Compared to the others	112.67	44.06	
P. 9	193.33	45.09	0.000
Compared to the others	98.02	33.89	
P. 10	126.66	35.47	0.344
Compared to the others	102.78	42.05	
P. 11	101.8	35.7	0.885
Compared to the others	104.7	42.81	

P. = Physician

Total surgical time (min) for umbilical hernioplasty

The average surgical time in umbilical hernioplasty was 59.31 min (95.00 % CI: 54-63 min, *SD* 29.9) (Figure 3).

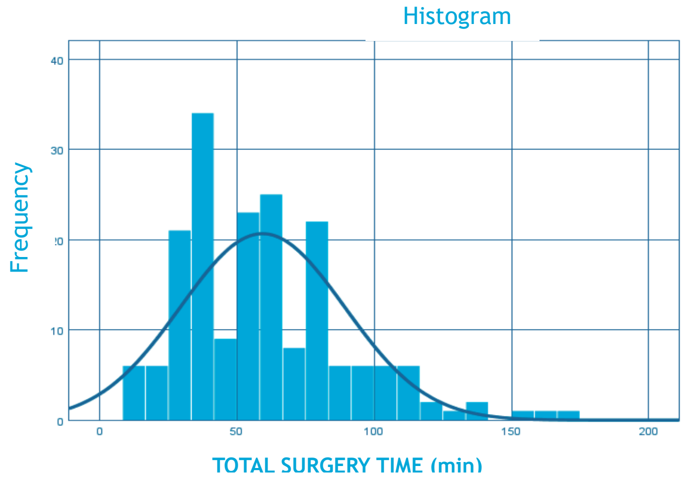

Figure 3. Histogram of total surgical time for umbilical hernioplasty

When the timed values were evaluated as a whole, the minimum recorded value was 10 min, and the maximum was 170 min.

Fourteen surgeons were evaluated, and the mean duration time for this procedure was obtained (Table 3). It should be noted that Physician No. 14 (mean = 94, *p* = 0.043) performed the procedure in a significantly longer time than the other evaluated surgeons. On the other hand, Physician No. 1 (mean = 42 min, *p* = 0.112) achieved the shortest average duration time.

Table 3. Comparative table of surgical procedure times for umbilical hernioplasty by each surgeon

Surgeon	Mean	Standard deviation	*P*
P. 1	42.8	14.53	0.112
Compared to the others	60.05	30.24	
P. 2	50.37	27.23	0.389
Compared to the others	59.71	30.04	
P. 5	56.65	30.03	0.674
Compared to the others	59.63	29.98	
P. 6	64.21	29.08	0.453
Compared to the others	58.6	30.04	
P. 8	57	25.97	0.835
Compared to the others	59.4	30.12	
P. 9	46.46	27.13	0.108
Compared to the others	60.28	29.96	
P. 10	48.95	19.34	0.076
Compared to the others	60.77	30.88	

P. = Physician

Total surgical time (min) for cholecystectomy

The mean duration for cholecystectomy was found to be 85.735 min (95% CI: 83-88 min) among the surgeons (Figure 4). The minimum time recorded during cholecystectomy was 15 min, while the maximum recorded time was 204.99 min.

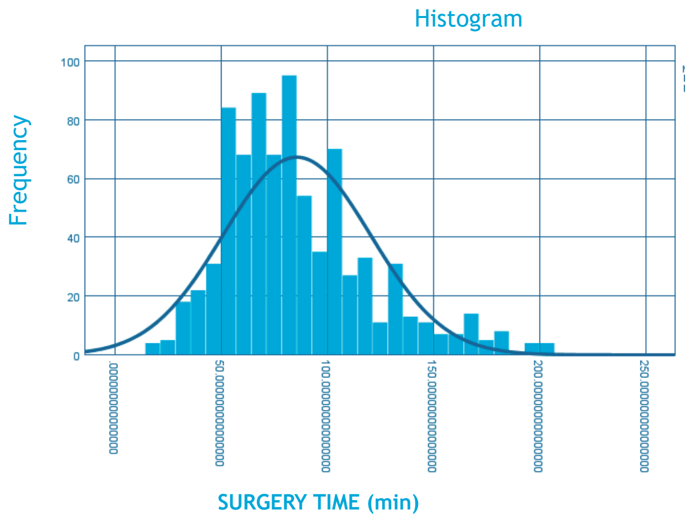

Figure 4. Histogram of surgical procedure time for cholecistectomy

The performance times of 14 surgeons were taken into account, and the mean time for each was obtained (Table 4). From these results, the study found that Physician No. 10 (mean = 60 min, p = 0.001) and Physician No. 12 (mean = 65 min, p = 0.004) performed the procedure in a significantly shorter time compared to the other surgeons. The comparison of the means of the evaluated surgeons showed that Physician No. 4 had the statistically longest duration (mean = 119 min, p = 0.00).

Tabla 4. Comparative table of surgical procedure times for cholecystectomy by each surgeon

Surgeon	Mean	Standard deviation	*P*
P. 1	67.8	27.8	0.114
Compared to the others	79.1	35.05	
P.2	72.3	20.06	0.417
Compared to the others	78.7	35.3	
P. 4	119.09	77.36	0.000
Compared to the others	42.11	33.91	
P. 5	76.9	78.57	0.799
Compared to the others	29.84	35.12	
P. 6	81.61	78.08	0.525
Compared to the others	28.7	35.39	
P. 10	60.32	80.06	0.001
Compared to the others	23.62	35.13	
P. 11	81.79	78.07	0.507
Compared to the others	51.49	32.35	
P. 12	65.22	80.21	0.004
Compared to the others	18.34	36.01	
P. 14	82.05	77.4	0.265
Compared to the others	33.94	34.94	
P. 15	92.6	78.28	0.36
Compared to the others	23.84	34.83	
P. 16	90.6	78	0.168

Surgeon	Mean	Standard deviation	*P*
Compared to the others	25.88	34.97	
P. 18	71.5	78.52	0.688
Compared to the others	9.53	34.89	
P. 19	88.48	47.15	0.098
Compared to the others	77.67	33.69	
P. 20	88.7	38.69	0.35

P. = Physician

Since several surgeries are included in the OR schedule, there are probabilities that all of them are on time, that none of them are on time or that there are combinations in which a certain number of surgeries are delayed while others are on time [16].

Calculation of the probability of surgery extension

According to the data previously obtained (Figures 1, 2, 3 and 4), most of the surgeries performed will take less time than the upper limit of the confidence interval (e.g., 97.5 % of unilateral inguinal hernioplasties will not take more than 80 min). Considering this, the probabilities of each of the resulting combinations of having three scheduled surgeries, each with a probability of being extended or ending early, were calculated (Table 5).

Table 5. Probability of procedure extension

First surgery		Second surgery		Third surgery		Probability
On time	97.5 %	On time	95.5 %	On time	97.5 %	92.69 %
				Extended	2.5 %	2.38 %
		Extended	2.5 %	On time	97.5 %	2.38 %
				Extended	2.5 %	0.06 %
Extended	2.5 %	On time	97.5 %	On time	97.5 %	2.38 %
First surgery		**Second surgery**		**Third surgery**		**Probability**
Extended	2.5 %	On time	97.5 %	On time	97.5 %	2.38 %
				Extended	2.5 %	0.06 %
		Extended	2.5 %	On time	97.5 %	0.06 %
				Extended	2.5 %	0.0016 %

One way to make these calculations is through the binomial expansion to the n power, where n is the number of events (surgeries) to be performed.

Thus, if two surgeries are performed in total:

- $(A + B)^2 = A^2 + 2AB + B^2$

The binomial expansion represents each of the existing combinations with respect to the first surgery being on time or delayed and the second surgery being on time or not:

- A^2 = the probability that two surgeries will be on time
- $2AB$ = the probability that one surgery will be on time and the other will not
- B^2 = the probability that both surgeries will be delayed

Making the corresponding substitutions, we obtain:

- $A^2 = (0.975)^2 = (0.975)\ (0.975) = 0.9025 = 95.06\ \%$
- $2AB = 2(0.975)\ (0.025) = 0.0475 = 4.875\ \%$
- $B^2 = (0.025)^2 = (0.025)\ (0.025) = 0.000625 = 0.0625\ \%$

Applied with three surgeries, we proceed to raise the binomial to the third power:

- $(A + B)^3 = A^3 + 3A^2B + 3AB^2 + B^3$

With this method, by raising the binomial $(A + B)^n$ (n = number of surgeries), all combinations and, therefore, all probabilities can be obtained. The higher the number of surgeries performed, the lower the probability that the full set of surgeries will be on time.

DISCUSSION

This study obtained the mean times for four different non-laparoscopic procedures (unilateral inguinal hernioplasty = 76 min, bilateral inguinal hernioplasty = 104.78 min, umbilical hernioplasty = 59.31 min, and cholecystectomy = 85.73 min). For unilateral inguinal hernioplasty, other studies have shown that the mean time for laparoscopic unilateral inguinal hernioplasty is 40.5 min (29.2-63.8 min), while for robotic surgery it is 75.5 min (59-93.8 min) [15]. A comparative study of laparoscopy vs. robotics showed that the mean time for laparoscopic unilateral inguinal hernioplasty was 68 min, while for robotic surgery, it was 88 min. This difference in times may result from the different techniques used (traditional, laparoscopic and robotic) and to the operating times of different surgeons within and between hospitals [17,18]. This is consistent with what was found in our study as the times between surgeons vary considerably. It is also important to note that approximately 25 % of the intraoperative delay time was due to avoidable interruptions and 60 % of these resulted from unnecessary activities or those that should have been performed prior to the procedure [19].

In a retrospective study involving 707 patients who underwent laparoscopic cholecystectomy (LC), the average time was 69 min [20], which is relatively shorter than that found in our study, i.e., 85.73 min. In another retrospective study conducted in Ecuador with 468 patients who underwent LC, an average time of 42.43 min was found [21]. This difference in time may be due to the teaching in hospitals, where the duration of the procedure may be extended by the learning curve of residents [22,23].

Regarding the probability analysis based on the standardized surgical times of our hospital, an interesting pattern is that the higher the number of scheduled surgeries, the lower the probability that all will be completed on time (Table 5). Nevertheless, if three surgeries (cholecystectomy) are scheduled, the probability that they will be extended is 0.0016 %, which represents an acceptable probability when scheduling.

In a study to assess duration accuracy, 97,397 surgeries were analyzed between 2017 and 2021. The overestimation of surgical time exceeded 60.00 %, with a median of 28 min, while the underestimation was 37.00 %, with a median of 30 min. Despite half of the surgeries were overestimated, this remains a waste of valuable OR time. Therefore, considering the factors that affect the duration of surgery contributes to improve the efficiency of OR scheduling [24].

In a study by Burgette et al. involving more than 700,000 cases, it is suggested that trainee participation significantly increases the duration of surgery. The magnitude of this increase is large enough to potentially affect direct and indirect costs, the institution, surgical efficiency, and possibly surgical outcomes as well [25]. A significant limitation in using historical data to estimate future surgical times is that previous cases of the same type of procedure and surgeon may not be available [26].

There are opportunity areas in our study: adding variables such as surgical assistants, anesthesiologists, nursing staff and biomedical characteristics of the patients. By increasing the level of prediction, a more accurate tool can be created. Machine Learning (ML) tools could even be used to improve the accuracy of the study, as was done by Babayoff et al. [27-28]. Utilizing real-time location systems with radio frequency identification (RFID) or Bluetooth technology, among others, allows for the identification of inefficiencies or bottlenecks, and ideally, they could provide automated responses or interventions to help address those inefficiencies as they arise [29].

Once the problem areas have been identified, the next step is to implement solutions. It is crucial that all relevant departments participate in the dialogue and discussion; however, it is equally important to have strong perioperative leadership. It would be convenient to identify a responsible person to lead the OR, manage scheduling and effectively communicate with the nursing and anesthesia surgical teams and other concerned personnel [30].

In conclusion, scheduled surgeries can be planned with standardized surgical times. It is necessary to have updated statistics on surgical procedures (average time to complete each procedure) as it is possible to detect and supervise more precisely the OR dynamics by identifying opportunity areas, thereby making the operating OR time more efficient for the benefit of the health systems and patients.

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Corresponding author:
Luis Bernardo Enríquez Sánchez
Address: C. Rosales, no. 3302, col. Roma Sur, C.P. 31350. Chihuahua, México.
Telephone: (614)-180-0800
E-mail: investigacionhcu@gmail.com

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ORCID iDs

Manuel David Pérez Ruiz	https://orcid.org/0000-0002-2729-1579
Luis Bernardo Enríquez-Sánchez	https://orcid.org/0000-0001-9143-3626
Carolina Martínez Loya	https://orcid.org/0000-0002-3917-9576
Miguel Eduardo Pacheco Pérez	https://orcid.org/0009-0008-4406-693X
Estefanía Garfio Mandujano	https://orcid.org/0009-0000-7522-5130
Jacqueline Rodríguez Rodríguez	https://orcid.org/0009-0006-3977-5593
Myriam Ramos Segovia	https://orcid.org/0009-0003-1968-203X
Carlos Eduardo Quiñones Gutiérrez	https://orcid.org/0009-0000-6781-5130