Impact of changed management policies on operating room performance and the distribution of patient categories

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Abstract

Background
To improve operating room (OR) performance during the daytime and to reduce surgeries at night without use of extra resources, a new resource allocation strategy and new policies for patient classification and OR booking were implemented at a tertiary referral hospital. This paper investigates the efficiency impact on OR performance for the different patient categories and the quantitative impact on the distribution of patient categories.

Methods
The before-and-after analyses were conducted on OR data involving 23,515 observations comprising elective (planned) and non-elective (unplanned) surgeries within the orthopaedic and general surgery department. The study period was calendar year 2007 (period 1) and July 2008 to July 2009 (period 2). Wilcoxon-Mann-Whitney test was used for calculation of statistical significance.

Results
There was a significant increased number of elective (n=335) and non-elective cases (n=436) between the two periods, both p<0.05. Despite a reduction by three (dedicated) ORs previously available for electives, a slightly higher amount of elective case time was handled with 26 % less use of overtime, p<0.05. The elective group had a higher share of the total patient population in both periods (68 % and 66 %, respectively). With regard to the non-elective categories, however, there was a major distributional shift. The proportion of high urgency cases (U1) was reduced
from 20 % to 12 %, indicating that almost 90 % of the surgeries could be planned minimum 24 hours in advance in period 2. Simultaneously, there was a significant growth of lower urgency cases (U2 and U3), both groups increased approximately 90 %, p<0.05. This increased workload was absorbed through enhanced daytime operating. The proportions of daytime operating for the two groups increased from 13 % to 29 % (U2) and 49 % to 65 % (U3). Consequently, the proportions of workload on evening, -night, - and weekend shifts declined. Additionally, the total number of nights without any surgery increased from 55 to 112 (of 315 and 316, respectively).

**Conclusions**

The interventions led to reduced variability and improved predictability, thereby increasing cost efficiency and allowing for higher daytime productivity. The synergistic effects of the redesign probably exceeded the isolated effects of the new management policies.

**Key words:** Dedicated operating room; Emergency surgery; Health care efficiency; Operations Management; Patient classification; Priority setting; Resource allocation

**Background**

Currently, limited health care resources face almost limitless demands. Therefore, advanced planning and scheduling tools are becoming increasingly important in hospitals. To improve operating room (OR) performance during the daytime and to reduce surgeries at night without use of extra resources, a series of interventions were implemented for elective (planned) and non-elective (emergency/unplanned)
orthopaedic and general surgery patients at a major tertiary referral hospital. The interventions involved a change of allocation strategy (from mixed to dedicated resources), and new policies for patient classification and booking of ORs (i.e. posting of non-elective surgical cases at the ORs).

**To dedicate or not to dedicate**

Operating room (OR) performance in hospitals with a mixed caseload of elective and non-elective patients is strongly influenced by the stochastic arrival of non-elective patients. To deal with the underlying uncertainties and variability inherent to OR processes, there are two common ways of allocating OR capacity for the non-elective group. One alternative is to distribute total variability over all ORs (reserving some capacity for non-electives in all ORs = mixed policy). Another alternative is to isolate the variability caused by non-electives in separate ORs (dedicating one or more ORs for non-electives, while the reminding ORs exclusively serve electives = dedicated policy). Hospitals have faced these allocation problems for decades, and different practices still exist. Recently published guidelines recommend a separation of elective and non-elective workload [1, 2]. In the literature, however, there is an absence of consensus on whether the production lines should be separated. It can be argued that a separation of planned and unplanned surgeries can reduce total variability, increase predictability, and improve responsiveness and overall production [3, 4]. This is supported by empirical studies comparing performance after a change of allocation strategy [5-7], and additional changes in management policies such as patient classification systems [8, 9]. Simulation studies, however, indicate that a separation of planned and unplanned surgeries is less cost effective and increases non-elective response time [10-12]. These studies conclude that insertion of slack in all the OR’s provides more flexibility for dealing with variation in non-elective volumes and case
time duration, whilst a dedicated policy ties up capacity whether there are patients or not. While a scarce amount of research have addressed the efficiency impact of similar changes on OR performance, most of these focus on the isolated effects of a single strategy change, such as one dedicated OR for a single department. Although one recent study focuses on elective patients and the non-elective categories [6], previous research commonly consider one or two patient groups only; the elective and/or the non-elective group. None of the papers, however, are investigating the efficiency impact of several interventions including three dedicated ORs, with regard to elective patients and the non-elective categories.

Factors influencing the distribution of patient categories

Pre-operative categorization (triaging) of surgical patients refers to the process of defining the priority of the management of patients according to their different medical priorities. The categories define the urgency of the patient’s treatment, for example (i) elective patients (within weeks or months) and (ii) non-elective patients. The latter group is divided into three (or more) categories; within 0-6 hours (U1), within 24 hours (U2), within 72 hours (U3). Interventions affecting policies for patient classification and OR booking may influence the prioritization process and can thereby alter the distribution of patient categories. Currently, there is no agreement on any level (strategic, tactic and operational) of health systems about which values should guide the decisions for priority setting [13]. Existing definitions of emergency surgery are not standardized across different jurisdictions (i.e. within and between countries), or across hospitals and departments [14]. Fitzgerald et al [15] conducted a survey questioning decision makers about urgency of a set of clinical conditions and appropriate waiting times for the patients. Their findings indicate that discrepancies in the decisions for acceptable timeframes for treatment can cause variability with
respect to the assignment of urgency of surgery for patients with similar conditions. The urgency of an intervention is not a constant factor. With the exception of time-critical emergencies (i.e. “true emergencies” where delays may put life, organ, or limb at risk), the decision-making processes around the prioritizations and scheduling of surgery are not only based on clinical evaluations. They are also influenced by non-clinical differentiators, such as logistical constraints (e.g. availability of resources and time), conflicting objectives, disparities in the perception of urgency, and competing priorities [15]. Cases can be assigned with a higher priority than the condition suggests to secure an earlier slot, i.e. gaming [16], or requests for surgery (OR booking) can be postponed to avoid cancellation of an elective case. Therefore, the clinical urgency is not necessarily identical to the order of priority. Prioritization dynamics is spurred by several mechanisms, for example by strategic decisions such as the current reimbursement system or the waiting-time guarantee system. By rewarding high volumes of surgeries it provides financial incentives for competition between departments to ensure profitability for their own holdings, thereby providing additional incentives for non-clinical prioritization. Although the concept of consistent prioritization and the development of standardized categories of clinical urgencies have been discussed in the literature, there is a lack research of this topic [14]. As far as we know, empirical investigations into the quantitative impact of altered policies for pre-operative categorization (triaging) on the distribution of patient categories have not yet been conducted.

To investigate the impact of the interventions, we conduct a before-and-after study of the OR data. Firstly, we examine the efficiency impact on OR performance in terms of changes in volumes and case time, with regard to the total population and the
different patient categories. Secondly, we assess the quantitative effect on the
distribution of patient categories. Finally, we address the influence on the distribution
of case time by shift for the three non-elective categories.

Methods

The setting
The study centre is a publicly financed tertiary referral hospital that provides elective
and non-elective surgery. The activities also include education and research. It serves
as a local hospital of a population of 275 000 and has several regional and national
tasks for the population in three nearby counties with a total of 630 000 inhabitants.
Excess emergencies cannot be diverted and treated elsewhere because there are no
alternative hospitals. Up until 2008 the hospital employed a mixed policy, but
subsequently a dedicated policy was adopted. The catchment population did not
change between the two periods.

The problem
Common problems at the ORs were delays and disruptions in the schedule.
Recurrently, non-elective cases were inserted into slots between planned surgeries
resulting in postponements of electives and overtime for staff, or cancellation of
elective surgeries. Alternatively, to avoid interruptions of the planned schedule, U2
and U3 patients were postponed and carried out during the evening or night when
resources were limited. However, these “overflow” cases could lead to cancellations
of surgeries the next day due to a lack of available beds at the post anaesthesia care
unit, or because the postponed case could bump another patient on next day’s
schedule. To avoid this, the deferred patients frequently suffered on-going delays following prioritisation of the next day’s non-elective list.

**The redesign**

A series of interventions were implemented during the first half of 2008. Firstly, a dedicated policy was adopted for the orthopaedic and general surgery departments. Three staffed ORs were dedicated for non-elective surgeries, whereas the fourteen remaining ORs were serving elective surgeries. The total number of available ORs was not changed. Secondly, to ensure consistency for patient classification and OR booking, new policies were implemented. In the first period, non-elective cases could be posted when the need for surgery had been identified. In the second period, requests could not be sent until the patient was ready for surgery. The patient classification was based on the individual physician’s evaluation in the first period. The new classification system was predominantly based on standardized categories (i.e. a number of diagnoses were pre-assigned with urgency levels/colour codes); U1 (red), U2 (yellow) and U3 (green). The time frame for each category remained the same. U1 cases were further sub-divided by the surgeon who posted the case (i.e. immediately, within minutes, or hours). Clinical evaluation would, if necessary, overrule the predetermined levels, thereby ensuring flexibility to recognize the dynamics of a patient’s clinical condition. The system was made transparent, i.e. the decision makers could assess each other’s prioritizations, which represented advantages for professional dynamics.
The data

The OR data comprises elective and non-elective orthopaedic and general surgeries collected by OR nurses at the time of surgery. The data specifies the urgency levels, the dates and times for OR booking (non-electives only), and OR entry and exit times. Case time (workload and operating is used interchangeably) is defined as the time difference between OR entry and exit. Period 1 refers to calendar year 2007, whereas period 2 refers to the two last quarters of 2008 and the two first quarters of 2009. The first two quarters of 2008 represented a transitional period that has been disregarded in the analysis. The data consists of 25,473 surgical cases performed in the two periods. We defined the shifts as follows; day shift is between 7 am and 16 pm, evening shift is from 16 pm to 12 am, and night shift is from 12 am to 7 am. In-hours refer to day shifts on weekdays. Out-hours/overtime refers to 4 pm to 7 am, all days. After the exclusion of seven low-activity weeks in each period (Christmas, Easter, and summer vacation) and deletion of observations due to coding errors such as OR exit before surgical end time, the final dataset consisted of 23,515 orthopaedic and general surgeries. The individual observations were aggregated per day. The total number of days included in the final dataset is 315 and 316 days in the first and second period, respectively. Wilcoxon-Mann-Whitney test was used for calculation of statistical significance. However, as an excessive number of zeros compromises the power of Mann-Whitney [17], this method was unsuitable to test for significance with regard to U1, U2 and U3 case times on the different shifts. Moreover, when assessing performance on each shift by urgency level, the distributions were severely skewed with different shapes for each period, and no simple analytic function (transformation) provided an adequate fit. Therefore, we did not apply additional methods such as statistical analysis of censored data.
Research Ethics

Ethics approval was not required for this study.

Results

Operating room performance

Table 1 displays the descriptive statistics. A total of 11372 and 12143 surgeries were performed in period 1 and 2, respectively. This represents a 6.8 % increase, p<0.05. Total case time increased 7.1 %, p<0.05, but out-hours operating did not change significantly (3, 2 %).

In the second period, the number of ORs available for electives was reduced from seventeen to fourteen, because three ORs were dedicated to non-elective cases. While there was a 4.3 % increase of elective cases (335 patients, p<0.05), there was no significant change of elective case time. Elective overtime was reduced by 26 %, p<0.05. Additionally, there was a reduction of daily elective case time variation; the standard deviation decreased from 1509 to 1227 (Fig. 1).

Non-elective cases and case time increased 12 % (436 patients) and 20 %, respectively (both p<0.05). While there was no significant change of out-hours surgery, there was a 47 % increase of in-hours operating and a 26 % reduction of case time at night (both p<0.05). At the same time, the total number of nights without surgery increased from 55 to 112. Also for the non-elective group, there was a
reduction of daily case time variation on day shifts (weekdays); the standard deviation was reduced from 352 to 281 between the two periods (Fig 2).

These findings indicate overall efficiency gains and improved performance for elective and non-elective cases in period 2. The discrepancy in growth between cases and case times for the elective and non-elective groups indicates a shift of surgeries with different case durations.

**Insert Table 1**

**Insert Fig. 1**

**Insert Fig. 2**

The changes in volumes and case times were very differently distributed for the three non-elective categories (Table 2). There was a 36 % decrease of U1 cases and case time (both p<0.05). The number of days with U1 surgery was reduced by six. U2 and U3 cases increased 92 % and 90 % (both p<0.05), respectively. The corresponding case times increased 96 % and 105 % (both p<0.05), respectively. For both groups, the increased workload was distributed over forty-seven additional days. As for the elective group, there was a discrepancy between the growth of U3 cases and case time. Despite the large reduction of U1 cases, non-elective cases increased (20 %). Since this growth solely consisted of cases with lower urgencies, we examined the distribution of patient categories in the two periods.

**Insert Table 2**
The distribution of patient categories

Fig. 3 illustrates the percentage distributions of the patient categories by the total, and the non-elective population. The elective group was by far the largest in both periods; 68% and 66% in period one and two, respectively. Although the percentage ratio between the elective and non-elective groups remained almost the same, the distribution of the non-elective categories changed substantially. Following the large reduction of U1 cases and the simultaneous growth of U2 and U3 cases, the great majority (65%) of non-elective patients were U2 and U3 cases in the second period. Consequently, whereas U1 cases accounted for 20% of the total population in the first period, only 12% were U1 cases in the second period. Hence, almost 90% of all patients could be planned at least 24 hours in advance. Further, almost 80% of the patients (electives + U3= 66% + 12%) could be planned minimum 72 hours in advance. These changes represented essential benefits for the planning process and the schedule.

Insert Fig. 3

Distribution of case time (U1, U2 and U3) by shift

The examinations of case time by shift for each non-elective category displayed major changes (Fig 4). For example, U2 case time on day shifts (weekdays) increased from 149 hours to 630 hours, which represents a growth exceeding 300%. This was possible because the number of day shifts (weekdays) with U2 surgeries increased with 147% (from 66 to 163 shifts).

Insert Fig. 4
These changes were differently distributed for the three categories. Therefore, rather than addressing the changes of case time that was distributed on a variable number of shifts, we examined the percentage distribution of case time by shift for each patient category in the two periods (Fig 5). In the first period, 36% of total U1 case time was conducted during day shifts (weekdays). This share was reduced to 29% in the second period. Consequently, a higher proportion of U1 workload was conducted during evenings, nights and weekends in the second period.

U2 and U3 surgeries on the other hand, were to a larger extent carried out during day time in the second period. In the first period, 13% of total U2 case time was handled during day shifts (weekdays). In the second period, this proportion increased to 29%. Similarly, the proportion of U3 case time on day shifts increased from 49% to 65%. Different from U1, out-hours operating for U2 and U3 were reduced. For U2, the proportion of case time on evening shifts decreased from 46% to 41%, and on night shifts from 11% to 4.4%. For U3, these proportions decreased from 21% to 17% and 3.6% to 0.7%, respectively. The proportions of weekend surgeries were reduced for both groups. These findings indicate that enhanced daytime operating absorbed this increase in total U2 and U3 workload. The additional shifts also allowed for a more even distribution of case time on day, evening, and weekend shifts in the second period, which is consistent with the reduction of daily non-elective case time variation.

Insert Fig. 5
**Discussion**

The overall results indicate efficiency gains in terms of improved flow and performance without use of additional resources. A significant increased amount of total workload (7.1%) was conducted without a concomitant increase of out-hours operating. A slightly higher amount of elective case time was handled with 26% reduced overtime. Elective case time increased despite the reduction by three ORs available for electives, indicating that in the second period the ORs were able to plan and operate more efficiently, avoiding "slack time" previously caused by insertion of non-elective cases. Simultaneously, daily case time variability for electives decreased, also indicating less "disturbance" from non-elective cases. Our data contains no information on postponements of elective surgeries or delays inflicted on elective patients in the two periods. This type of information might have indicated additional benefits. An advantage of separating elective and non-elective production lines is that this provides the opportunity to establish “fast-track ORs”, which can improve elective performance further.

Resulting from the re-distribution of patient categories, the 20% growth of non-elective case time solely consisted of lower urgency cases; this will be elaborated under the next subsection. While there was no significant change of non-elective out-hours operating, in-hours operating increased 48%, and case time at night was reduced 26%. Despite the increased workload, there was a simultaneous reduction of daily case time variability. Altogether, the findings demonstrate that the increased workload was handled through enhanced operating during daytime. A more even distribution of workload on day shifts also facilitates improved performance.

Different from studies considering the effects of only one dedicated OR, we assessed
the impact of three dedicated ORs. By distributing non-elective variability over three ORs, higher flexibility is offered compared to one dedicated OR.

The analyses with regard to the three non-elective subgroups are somewhat complicated due to the changes that coincided in time. In addition to a re-distribution of the patient categories, there were also changes with regard to case time on various shifts and the number of different shifts with surgery. These alterations were differently distributed for the three categories. Therefore, we focused on the percentage distribution of case time on the various shifts. Since the catchment population did not change between the two periods, we can presume similar case mix.

The large distributional shift within the non-elective population demonstrates the quantitative impact of the interventions. Firstly, the introduction of the dedicated ORs eliminated competing priorities between elective and non-elective cases. One source that could previously cause overflow patients was hence removed. Due to the dedicated ORs, it could to a larger extent be expected there would be available capacity to perform non-elective surgery within maximum acceptable waiting time. This contributed to a reduction of the incentives for non-clinical prioritization.

Secondly, the adoption of the new policies may also have contributed to this shift. Increased consistency with regard to patient classification and OR booking reduced the influence of non-clinical priorities. As a result, there was less variability of the prioritization process. The inherent uncertainty and variability characterizing non-elective patients do not only apply to uncertainties and variability in arrival patterns,
resource requirements and process durations, but also to differentiators influencing the priority-setting, not all of which are stochastic.

The large reduction of U1 demand can be attributed to higher levels of agreements and consistency in the requirements to meet U1 criteria. We can therefore presume that U1 cases in the second period to a larger extent consisted of “true emergencies”. Regardless of policies, patients requiring immediate attention always receive first priority and will be operated as soon as possible. The number of, - and OR accessibility for high priority cases is negligibly affected by management interventions. Efficiency improvements are more likely to manifest as improved OR accessibility for lower priority cases resulting from less delay and/or fewer cancellations previously caused by high priority cases [6]. Accordingly, in the second period, the changes of U1 cases on the various shifts merely reflect the arrival pattern of these patients.

The simultaneous growth of U2 and U3 cases can be ascribed to cases previously classified as U1. Additionally, a reclassification of previous elective cases to U2 or U3 may also have contributed. This is consistent with the smaller increase of elective (n=335) compared to the larger increase of non-elective (n=436) cases. The discrepancy between the growth of cases and case times for elective and U3 cases also indicates a shift of surgeries with different case durations.

The distributional shift represented essential benefits for the scheduling process. In the second period, surgery for almost 90 % of all patients could be planned minimum 24 hours in advance, whilst almost 80 % (U3 and electives) could be planned
minimum 72 hours in advance. Accordingly, increased predictability allowed for a more precise and efficient scheduling.

Despite the large growth of U2 and U3 surgeries, enhanced daytime operating absorbed the major part of this workload. Consequently, reduced proportions of U2 and U3 surgeries were conducted on evening, - night, - and weekend shifts. There was also a large reduction of the number of nights with surgeries. Altogether, this indicates that previous “overflow” cases to a larger extent were carried out during day shifts in the second period. Increased in-hours operating, less variability, higher predictability and reduced overtime is not only cost effective, but can also increase patient and staff satisfaction and reduce fatigue for both groups.

There are several additional benefits of conducting the majority of surgeries during in-hours. For example, increased seniority of the surgeons and anaesthesiologists performing difficult cases [18, 19], which also facilitates improved resident supervision and training opportunities, all of which may reduce errors and complications [20-22]. A more even distribution of workload throughout the day, - and evening shifts diminishes peaks of workload, which is favourable for staff and patients in terms of less strains and thereby reduced medical errors [22, 23]. More emphasis should be put on these additional benefits when the cost efficiency of a redesign is evaluated.

We were not able to isolate and quantify the effects of the different policy changes. By itself, the new policies for patient classification and OR booking might have had an impact on performance even without the introduction of dedicated ORs. The
implied transfer of previous U1 cases to U2 or U3 facilitates better scheduling of
emergency surgeries and this would probably also have had an impact with a mixed
policy. We did not conduct analyses of waiting time (elapsed time from posting of
cases until OR arrival). The changed booking policy would in itself reduce monitored
waiting time, and we could not distinguish this effect from additional influences of the
redesign (i.e. whether there was a reduction of monitored and/or real waiting time).

We propose future research focusing on: (1) analyses of health outcomes such as
complication, - mortality, - and cancellation rates following a change of classification
and booking policies; (2) investigations of whether such policy changes improve the
estimation of future demand; (3) determination of the required level of demand that
would justify the introduction of dedicated ORs, including (4) development of
generalizable algorithms for estimation of the number of dedicated ORs based on
demand.

**Conclusions**

This paper documents the efficiency impact on operating room performance in terms
of workload and number of cases with regard to the total patient population and the
different patient categories, following the implementation of new management
policies. Additionally, it demonstrates the effects on the distribution of non-elective
workload on different shifts, and the quantitative impact of the policy changes on the
distribution of demand for the different patient categories. The latter finding not only
highlights the importance of accounting for all patient categories within planning and
scheduling tools and when evaluating efficiency gains of interventions, but also
illustrates the dynamics and impact of non-clinical prioritization contributing to
prioritization variability with potential adverse effects on performance. The overall findings support that the interventions led to reduced variability and increased predictability, thereby increasing cost efficiency and allowing for higher productivity in the treatment of all patient groups. The synergistic effects of the redesign probably exceeded the isolated effects of the new management policies. Improvement, however, cannot be attained through new strategies alone; a precondition to succeed is an adequate communication and collaboration between professionals at the strategic, tactic and operational levels, recognizing the full range of dynamics characterizing health care processes.

**Competing interests**
The authors declare that they have no competing interests.

**Authors' contributions**
BS was the primary analyst and principal author of the paper. BIH was involved in drafting, analyses interpretations and reviewing the paper. OIL participated in the data analyses and reviewed the paper. SF was involved in data collection, analyses interpretations and revising the paper. All authors read and approved the final paper.

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Abbreviations
OR(s), operating room(s); U1, U2 and U3, urgency 1, 2 and 3; CT, case time

References

Figures

**Figure 1 Daily elective case time, two-way graph.**
Each circle corresponds to one day; the lines indicate the 5 and 95 percentiles; the areas without observations represent low-activity periods, such as Public Holidays and vacations.

**Figure 2 Daily non-elective case time (day shifts, weekdays), two-way graph.**
Each circle corresponds to one day shift on a weekday; the lines indicate the 5 and 95 percentiles; the areas without observations represent low-activity periods, such as Public Holidays and vacations.

**Figure 3 Percentage distributions of patient categories by population.**
A: Elective, U1, U2 and U3 percentages of total population.
B: U1, U2 and U3 percentages of the non-elective population.

**Figure 4 Percentage change of U1, U2 and U3 case time by shift and number of day, -evening, - night, - and weekend shifts with surgery.**

**Figure 5 Percentage distribution of total U1, U2 and U3 case time by shift.**
## Tables

Table 1 Descriptive statistics, total population and the two main patient groups.

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<th>Population</th>
<th>Variable</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Change, %</th>
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<td>Number of patients (n)</td>
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<td>SD daily case time (day shift, weekdays)</td>
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*Note. *$p \leq 0.05$
Table 2 Descriptive statistics, non-elective patient categories.

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<th>Period 2</th>
<th>Change, %</th>
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<td></td>
</tr>
<tr>
<td>U3</td>
<td>Number of patients (n)</td>
<td>778</td>
<td>1480</td>
<td>90*</td>
</tr>
<tr>
<td>U3</td>
<td>Total case time (hours)</td>
<td>1758</td>
<td>3612</td>
<td>105*</td>
</tr>
<tr>
<td>U3</td>
<td>Number of days with surgery</td>
<td>261</td>
<td>308</td>
<td></td>
</tr>
</tbody>
</table>

*Note. *p ≤ 0.05*
Figure 1
Figure 2
Figure 3

A. Total Population

- P1: 68%
  - Elective: 20%
  - U1: 9.6%
  - U2: 12%
  - U3: 5.4%

- P2: 66%
  - Elective: 12%
  - U1: 12%
  - U2: 9.6%
  - U3: 5.4%

B. Non-elective population

- P1: 62%
  - U1: 17%
  - U2: 21%
  - U3: 36%

- P2: 35%
  - U1: 29%
  - U2: 17%
  - U3: 36%
Figure 4