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ORIGINAL INVESTIGATION

Contribution margin per hour of operating room to reallocate unutilized operating room time: a cost-effectiveness analysis

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Abstract
Background and objectives: Contribution margin per hour (CMH) has been proposed in healthcare systems to increase the profitability of operating suites. The aim of our study is to propose a simple and reproducible model to calculate CMH and to increase cost-effectiveness.
Methods: For the ten most commonly performed surgical procedures at our Institution, we prospectively collected their diagnosis-related group (DRG) reimbursement, variable costs and mean procedural time. We quantified the portion of total staffed operating room time to be reallocated with a minimal risk of overrun. Moreover, we calculated the total CMH with a random reallocation on a first come-first served basis. Finally, prioritizing procedures with higher CMH, we ran a simulation by calculating the total CMH.
Results: Over a two-months period, we identified 14.5 hours of unutilized operating room to reallocate. In the case of a random ''first come–first serve'' basis, the total earnings were 87,117 United States dollars (USD). Conversely, with a reallocation which prioritized procedures with a high CMH, it was possible to earn 140,444 USD ($p < 0.001$).
Conclusion: Surgical activity may be one of the most profitable activities for hospitals, but a cost-effective management requires a comprehension of its cost profile. Reallocation of unused operating room time according to CMH may represent a simple, reproducible and reliable tool for elective cases on a waiting list. In our experience, it helped improving the operating suite cost-effectiveness.

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Introduction

In the last decades, industrialized countries have witnessed a continuous and uncontrolled rise in healthcare costs.[1] The sustainability of healthcare systems is intended as long-term practices to maintain and improve the standard of care by an economical point of view, without negatively impact on social and health aspects of the community. Sustainability will be one of the crucial challenges that all developed countries will have to face in the near future. The political pressure on hospitals and clinics to reduce healthcare expenses will increase in the next years and ultimately affect daily clinical decisions. Therefore, the relevance of economic criteria in clinical decision-making will increase consensually.[2] The conundrum of healthcare systems sustainability has become a well-recognized ethical issue, with the consequent risk of cream-skimming (i.e., a practice where only patients and medical/surgical services bringing significant profits to the healthcare facility are selected) and unequal access to healthcare.

The introduction of the diagnosis-related group (DRG) in the 1990s overall helped in containing costs, aiming to increase turnover, lower the length of stay[3] and perform more cases. DRG-based payments were gradually introduced in many other countries and nowadays have become the principal form of hospitals reimbursement in most developed countries.[4–6] The cost-effectiveness ratio of a surgical activity is mainly determined by an optimization of its fixed costs.[7,8] Personnel costs represent the major contributor to fixed costs and go in parallel with the duration of surgical procedures, namely operating room time. Thus, the operating suite is a service at constant risk of switching from being a source of profit to being a source of important losses for the hospital. Nevertheless, a hospital's mission implies offering some services to the population even when they are not profitable. In order to increase profitability without compromising accessibility, operating room time may be allocated by prioritizing elective cases with a higher contribution.[8–10]

The contribution margin (CM) represents the difference between the DRG-based reimbursement and variable costs of a surgical procedure. The calculation of CM has already been used in some healthcare settings to assess the profitability of a given service or department, with important implications for the hospital's policy. The concept of the CM has become important in healthcare management, particularly in relation to the DRG. The CM provides one way to show the profit potential of a particular surgical intervention and helps to cover fixed costs. However, the calculation of the CM of surgical cases is not a valuable parameter to assess its profitability, unless it is related to time, i.e., the time required for a given procedure.[11]

The aim of our study is to propose a simple and reproducible model to calculate the CM per hour (CMH), to evaluate a possible economic gain, and, ultimately, to increase cost-effectiveness.

Methods

Setting

Based on real data from the operating suite of a Swiss secondary level public hospital, Bellinzona Regional Hospital, we identified the ten most-commonly performed elective non-oncological surgical operations in 2017 (Fig. 1). No informed consents nor institutional review board approval was required since all financial data were fully anonymized, in accordance to the present Swiss legislation.

Data collection

For each operation, we considered its total DRG-based reimbursement, variable costs and procedural time. Consequently, we calculated the CMH. In particular, the CMH was defined as the reimbursement for a procedure according to DRG-grouping minus variable costs divided by the average calculated length of the surgical procedure.[6] Fixed costs are those that do not vary with outputs, such as equipment, buildings, and salaries. Variable costs, which change proportionally to output, were defined in this case as operating room costs directly attributable to the patient such as test reagents, medications and disposable materials and supplies (non-fixed costs). The length of the surgical procedure was defined as the time between the onset of anesthesia in the operating suite and the entrance in the recovery room at the end of the surgical intervention; it was rounded to the closest quarter of hour. Over a two months period, we quantified the portion of total staffed operating room time represented by the unused operating room time. Such time could can be reallocated to elective surgical activity with a minimal risk of overrun. The unutilized total staffed operating room time was defined as the total time with planned personnel in a day or week that was not exploited for surgery (for example in the case of a cancelled operation or procedures ending earlier than planned). The minimum risk of overrun was defined as the occupation as close as possible to 80% of available elective slots on a given day.[12]

Data simulation

We eventually calculated the cumulative CMH for every surgical intervention as the total CMH obtained with a reallocation of the unexploited operating room time on a first-come first-served basis among the waiting list of surgical operations at our institution. Finally, we ran a simulation calculating the cumulative CMH over that period with a simulated reallocation of the unexploited operating room time by prioritizing procedures with a higher CMH from the waiting list. All financial data is expressed in United States dollars (USD): Swiss Franc to USD exchange rate = 1.05 (last updated on 06.29.2020).

Statistical analysis

We used MedCalc Statistical Software version 19.2.6 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2020). Descriptive statistics were presented as a mean with standard deviation (SD) for continuous variables. The average reimbursement of CMH and the total CM were calculated for the ten most commonly performed surgical operations during the study period and for the simulation. The Student's *t*-test assuming independent variable was applied to evaluate CMH differ-

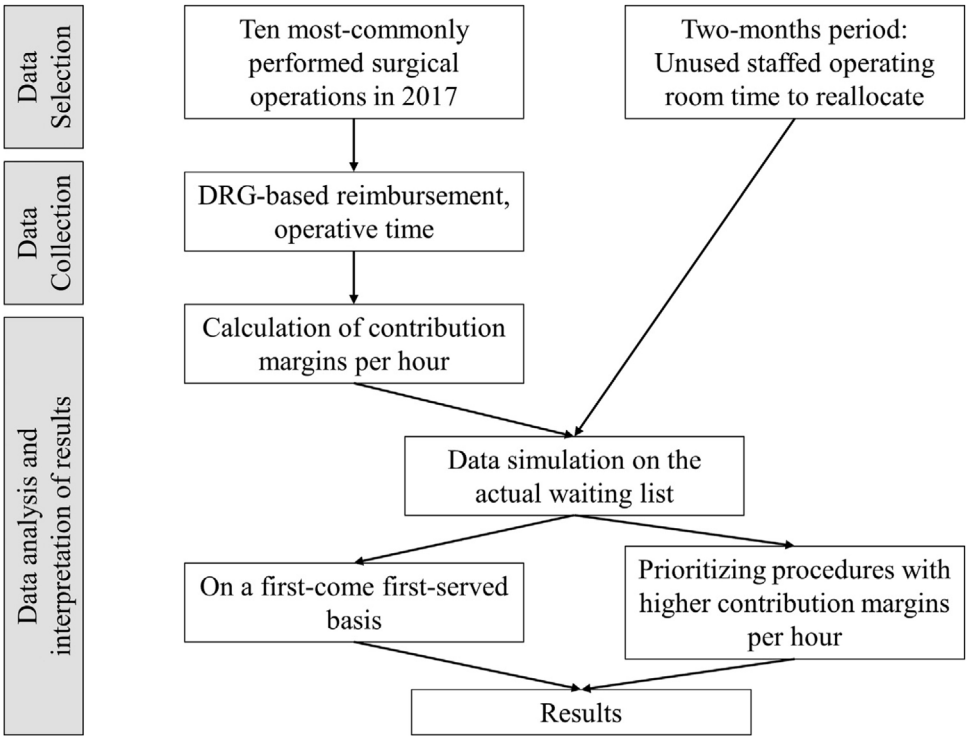

Figure 1 Flow chart of the study design.

ences between the groups (first come–first served group vs. higher CMH group). The threshold of statistical significance was set at $p < 0.05$.

Results

The CMH of the ten most-commonly performed elective surgical operations are reported in Table 1. Soft tissue operations (e.g., skin lesions, skin transplants), trans-urethral resection of the prostate and total hip replacement yielded a contribution margin between 9,000 and 10,500 USD per hour.

As second step of the analysis, we identified 14.5 hours of unused operating room time over a two-month period that could be reallocated with a minimum risk of overrun according to Green L et al.[12] According to the simulation, while the actual cumulative CMH was USD 87,117 (Table 2), the hypothetical cumulative CM achievable by prioritizing procedures with the highest CMH of operating room time would have been USD 140,444 (mean CMH over the study period = USD 5,989 ± 1,857 vs. mean CMH of the simulation = USD 9,406 ± 2,814, $p < 0.001$). Since only elective procedures were prioritized according to this criterion, access to urgent surgery was not jeopardized. Therefore, the CMH of operating room time-based approach was applied to elective surgical cases on the waiting list to reallocate the unutilized operating room time. Details are reported in Table 3.

Discussion

The potential economic impact of CMH of operating room time, to rationally reallocate unexploited operating room time to elective procedures on the waiting list, may be enormous. In fact, during the 2-months simulation period described in the present study, the actual cumulative CMH (USD 87,117) could be increased by 61% (hypothetical cumulative CMH: USD 140,444).

Effective reallocation of unutilized operating room time is a convenient tool to improve global cost-effectiveness of the operating theatre and has therefore strong strategical implications. Ideally, the allocation of staffed operating room time should fit exactly with the requirements of surgical services.[13,14] Although different techniques exist to allocate surgical slots and to minimize under-used operating room time, given the nature itself of the surgical activity, operating room managers always have to administer some unutilized operating room time.[15–17]

CM may be a straightforward criterion to incorporate economic ponderations into clinical and managerial decision-making by simply prioritizing reallocation of unexploited operating room time among surgeons and surgical services.[18] However, CM can be a misleading concept: a single operation, in fact, may have a very high absolute CM, but, in parallel, be very time consuming. Thus, reallocating unused operating room time to procedures with a high absolute CM could also represent a loss in terms of cost-opportunity. Time may be employed more effectively if redistributed to other different shorter procedures with a higher CM related to the effectively needed operating room time.[12,18] This specific issue raises the problem of opportunity costs; in fact, all reasonable alternatives should be examined before making a decision that involves resource allocation, since opportunity costs represent the profit lost when one alternative is selected over another. In fact, identifying and reallocating unutilized staffed operating room time with a minimum risk of overrun implies the

Table 1 The ten most-commonly performed surgical operations in 2017 with contribution margin per procedure and contribution margin per hour.

Procedure	Number of operations	Contribution margin per procedure, USD	Length of the surgical procedure, hours (SD)	Contribution margin per hour, USD (SD)
Soft tissue operations	35	18,269	1.75 (0.3)	10,439 (2,026)
Trans-urethral prostate resection	37	7,327	0.75 (0.2)	9,769 (2,699)
Total hip replacement	62	13,627	1.5 (0.4)	9,085 (2,720)
Open inguinal hernia repair	43	6,010	0.75 (0.2)	8,013 (2,409)
Trans-urethral bladder resection	86	5,856	0.75 (0.3)	7,808 (5,292)
Hysteroscopy	30	5,789	0.75 (0.3)	7,719 (5,705)
Laparoscopic cholecystectomy	157	6,184	1.0 (0.3)	6,184 (1,696)
Arthroscopic meniscectomy	31	3,985	0.75 (0.2)	5,313 (1,380)
Laparoscopic ventral hernia repair	104	4,115	1.0 (0.2)	4,115 (748)
Gastric by-pass for morbid obesity	31	10,308	3.0 (0.7)	3,436 (951)

Data is expressed with mean and standard deviation (SD) in parentheses. Financial data is reported in United States dollars (USD).

Table 2 The reallocated surgical operations during the study period with contribution margin per hour on a first-come first-served basis.

Procedure	Number of operations	Cumulative length of the surgical procedure, hours	Cumulative contribution margin, USD
Hemorrhoidectomy	2	2	8,718
Fistula for hemodialysis	1	1.5	11,112
Video-assisted thoracoscopy	1	1.25	9,838
Hysteroscopy	2	1.5	11,578
Tension free obturator tape positioning (TVT-O)	1	1.25	4,955
Arthroscopic meniscectomy	1	1	3,985
Laparoscopic ventral hernia repair	1	1.25	4,115
Laparoscopic ileostomy	1	2	13,333
Trans-urethral bladder resection	1	0.75	5,856
Total hip replacement	1	2	13,627
TOTAL	**12**	**14.5**	**87,117**

Financial values are expressed in United Stated dollars (USD).

Table 3 The simulation of the surgical operations during the study period with contribution margin per hour.

Procedure	Number of operations	Cumulative length of the surgical procedure, hours	Cumulative contribution margin, USD
Soft tissue operations	1	1.75	10,439
Trans-urethral prostate resection	5	3.75	48,845
Total hip replacement	2	3	18,170
Open inguinal hernia repair	3	2.25	24,039
Trans-urethral bladder resection	4	3	31,232
Hysteroscopy	1	0.75	7,719
TOTAL	**16**	**14.5**	**140,444**

Financial values are expressed in United Stated dollars (USD).

opportunity of increasing revenues. In this perspective, the potential choice to not reallocate these resources represents an opportunity cost. Moreover, social and economic costs of a delayed operation that, due to its low CMH, is not prioritized should be considered as well. On the other hand, operations with a high CMH would be prioritized and, despite obvious difficulties in estimating actual costs, opportunity costs may be balanced between delayed/anticipated operations. Another point is represented by unexploited staffed operating room time in a context in which trained personnel is not engaged in clinical activity and can be reallocated to alternative but still necessary tasks, such as inventory, bureaucracy, teaching, etc. This exploitable time would be reduced to the limit of minimum overrun risk and such activities should be redistributed. This would determine a cost opportunity, but being such activities flexible, we could

assume a low (although not neglectable) impact on efficiency. Opportunity costs may represent an important factor to take into account and further studies are needed to assess their relevance.

From an economical point of view, the need for a criterion to prioritize resource allocation in the perioperative setting is prone to many conceptual errors. Each elective adjunctive procedure does not necessarily represent an increase in hospital revenues. A given operation may even have a negative CM when it produces an operating room overrun, thus causing personnel overtime, which can even double the fixed cost of one hour of operating room time. An effective operating room management must therefore aim at minimizing both under-used and over-used operating room time, by implementing both daily tactical decisions and long-term strategic choices such as slot design and allocations.[16]

The systematic application of our allocation criterion on a vast scale could have a significant impact on the cost-effectiveness of operating suites and ultimately on total hospitals revenues. Moreover, the adoption of the concept of CMH in operating room management is not only an effective managerial tool which can contribute to implement the cost-effectiveness, but also a strategic tool for the hospital/clinic as a whole. In fact, through a more cost-effective allocation of its resources, a hospital could also choose to promote a specific sector of its surgical activity, which would contribute the most to the overall structure sustainability.[8,18] On the other hand, the risk of a CMH-based approach in the allocation of healthcare resources such as operating room time would be a potential cream-skimming process, that selects only the most profitable surgical cases within a given case-mix, which would represent a critical ethical issue, particularly for a public hospital. Similarly, hospital administrators/managers may decide to prioritize surgeons who can complete operations faster, but the surgical ability is not the only factor affecting the operative time and CMH. In fact, many time-consuming surgical steps are procedure- and patient-specific, so the risk would be of selecting patients in which a fast and uncomplicated operation can be expected, or even selecting surgeons who select patients. The risk would be again that of a cream-skimming process for surgeons and patients, affecting equal access to healthcare. In our opinion, it is of utmost importance to be as neutral as possible and not to consider surgeons individually, though this model might be prone to such issue. In order to avoid such risks and preserve equal accessibility to the operating suite, the inclusion of CMH among the criteria to allocate operating room time should be reserved exclusively to unused staffed operating room time. It could improve this resource utilization according to a cost-effectiveness criterion, rather than on a simple ''come first–serve first'' basis.[9] Obviously, the most common elective procedures end up occupying the vast majority of the reallocated operating room time, as they are the main constituents of surgical services waiting lists. Only the ten most-commonly performed surgical operations were considered in this study. Rarely performed operation, even with a more profitable CMH, could be difficult to be promptly reallocated and may not contribute to shorten waiting lists.[19] However, this practice may be uneconomical for a public hospital, as giving regular priority to elective procedures with a lower CM has a profound impact on the operating suite cost-effectiveness. On the other hand, the optimization of surgical procedures with a low CM should be considered of primary importance. In this way, as part of the cost-effectiveness analysis of surgical procedures, a low CM could indicate the lack of a cost-effective resource consumption. Although a low CMH is not necessarily associated to inefficient resources' optimization, workflow processes may be evaluated for possible improvements.

Moreover, the allocation of public resources should not be simplistically dismissed as unethical or in some way subordinate to more important clinical considerations. On the contrary, in a context of increasingly limited resources, cost-effectiveness and thus the sustainability of care systems assumes a very strong ethical connotation, as any unnecessary resource consumed for a patient is eventually denied to another in the future. According to Dexter D. et al.,[16] the CM may not be the goal itself, but it is a tool that hospital administrators can use to cover fixed costs and still have sufficient funds remaining for the society's common good. If a hospital plans to expand its services to the poor, fund-increasing research, and so-forth, then it must also identify and maintain an appropriate mix of larger-margin services.[16]

Finally, this is just one aspect of the potential increase in hospital revenues in the long run, in the case such approach to operating room management is systematically applied. In fact, providing incentives such as attribution of more operating room time to a given surgical activity would produce positive consequences, such as the positive impact on the public image of a given hospital or clinic. As a consequence, it could become a referral center for a given surgery and consequently attract more patients suffering from certain conditions, eventually leading to the performance of procedures with a high CMH.

The potential values of this model are its feasibility, reliability and reproducibility among hospitals that adopt a DRG-based reimbursement. Our results are not directly reproducible in terms of economic revenue but they give a potential basis to simply apply this model to other institutions. A retrospective analysis of a 2-months period collecting the DRG-based reimbursements, variable costs and operative times of surgical interventions should be enough. This simple model should easily help in increasing the cost-effectiveness of operating rooms according to specific hospital settings.

Our study has some limitations. Firstly, the analysis was based on data produced by a 2-months study period only in order to provide reproducibility and applicability. Longer data analyses are necessary to validate this model and to test reliability. Secondly, present data were based on a service operating on a DRG system basis and its conclusions might not be directly applicable to all reimbursement systems. Capitation and fee-for-service models are the two main methods of reimbursement. The fee-for-service is divided into cost-based reimbursement, charge-based reimbursement and prospective payment. CMH cannot be applied in the capitation model, while in the fee-for-service models it should be retrospectively possible in the cost-based and the charge-based reimbursements. In the prospective payment, which include DRG-based reimbursement, it should be easier applicable, as demonstrated by our study. In Brazil, the predominant reimbursement model is the fee-for-service and, therefore, CMH may be used.[20] At our

institution, a peculiar type of DRG reimbursement system, called Swiss-DRG,[5] is currently adopted and it shares many similarities to DRGs in other European countries and the United States.[21–23] That being said, even if reimbursements may have a slightly different CMH according to which healthcare systems is considered, results should remain comparable. Moreover, economic data are extremely context sensitive and may change significantly among different countries: for example, reimbursements, costs of personnel, costs per unit of operating room time are extremely different and can change the results accordingly, thus affecting their reproducibility. However, even if the entity of revenues and costs may change in terms of absolute values, the principles according to which the analysis has been conducted remain valid across different contexts: the staffed operating room time is the most relevant surgical fixed cost, affecting the whole economics of the clinical perioperative process. In order to optimize hospital revenues, two options remain valid: on the one hand, the increase in patients' turnover and the performance of more cases in the same available staffed hours; on the other hand, the completion of more cases with a higher CMH of operating room time.[16,17]

Finally, as already mentioned, these economic aspects are not the only criteria according to which the surgical activity of a given hospital should be organized and managed. In fact, more important criteria may be the direct consequences of a hospital's mission and its strategy in the long run. The latter, for example, may contemplate the acceptance of incurring in a temporary loss in cost-opportunity as a form of investment, in order to incentivize a given surgical activity, which is regarded as strategic. In fact, as it usually happens in other contexts with regard to the exploitation of precious resources, also the allocation of the operating room time should be rationally considered as an important strategic asset and used accordingly.[17] Shortening the waiting list of a given surgical service by constantly allocating more operating room time in its favor, in the long run, shapes the image of the hospital in the direction of a referral center in that kind of procedure, with direct positive consequences on outcomes and quality of the services provided. Of course, this cannot be the case for a public hospital, which has specific obligations toward society in providing whatever services are required, independently of their profitability. In this setting, the use of CMH of operating room time of given surgical procedures may also be a helpful tool to contribute to hospital sustainability.

Summary

In conclusion, as complex issues keep seriously jeopardizing the overall sustainability of most healthcare systems in developed countries, economic considerations are assuming a new ethical dimension and are increasingly incorporated into the decision-making process by healthcare managers. Surgical activity may be one of the most profitable activities for hospitals, but a cost-effective management of an operating suite demands a comprehension of its costs profile. To summarize this last aspect, the main factor affecting an operating suite cost-effectiveness is a rational utilization of its staffed total operating room time, in order to maximize occupation while avoiding overruns. Reallocation of unused operating room time should be performed according to ethical and economic principles. CMH may represent a simple, reproducible, and reliable tool in the setting of operating room management. The CMH-based reallocation of unused staffed operating room time to elective cases on a waiting list could improve the operating suite cost-effectiveness. Validation studies are needed to confirm the reliability of our model.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.bjane.2021.03.024.

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