

## The integrated OR Efficiency and effectiveness evaluation after two years use, a pilot study

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### Abstract

**Objectives** Technology evaluation of integrated/digital OR is needed since very little literature has been published on the subject. The integrated OR is a technological solution intended for minimally invasive surgery where the surgeons have complete control of the environment, devices and image distribution. Before such an investment, Health Technology Assessment can be used as a method to evaluate what vendors' state, i.e. the fact that the integrated OR is a very effective and efficient solution. Then a follow-up evaluation could be useful after the installation to test the users' satisfaction and give suggestions to the community about real-experienced integrated OR advantage.

**Methods** A multiple answer questionnaire has been handed to 17 surgeons and 9 scrub nurses from Varese Town and University Hospital to evaluate the degree of satisfaction after 2 years of use of integrated ORs.

**Results** Surgeons and scrub nurses agree that the integrated OR can be very effective in increasing quality, risk reduction and surgery time reduction through the use of digitalized video acquisition system, boom-mounted devices and multiple displays. Scrub nurses are a little bit more confident than surgeons that medical device control could reduce the confusion inside the OR and reduce the number of setting errors. A very positive judgment was given to the system's teaching capabilities, but both surgeons and scrub nurses agree that a great degree of education and a cultural change are needed to use the system in a correct and complete way.

**Conclusions** Results show that there is a deep appreciation of the system which proved to be efficient (reducing surgery time and enhancing surgical quality) and effective. This is a pilot study based on few collected data, but the questionnaire could be handed to many hospitals where integrated ORs are present, in order to achieve a significant degree of assessment and find common topics to be considered fundamental especially in the evaluating phase.

**Keywords** Digital OR · HTA · Efficiency · Effectiveness

### Background

Technology evaluation is considered a must in nowadays Health Care Systems, especially when a significant monetary investment is required. Many are the aspects to be taken into account, such as technical specifications, impact on facility from a structural and fixture stand point, organizational issues and costs. This is why Health Technology Assessment (HTA) is widely recognized as a method to evaluate health technology from a systemic and multidisciplinary standpoint, allowing a deep interaction between need for innovation, clinical advantages and cost rationalization. Its' interdisciplinary contents and process integrate the contributions of multiple fields to produce and communicate information reflecting not the whims or interests of an individual scientist but the contribution of scientific inquiry to policy-making [1,2]. Moreover, such a methodological approach provides decision makers with a support that can be based on a multidimensional set of data regarding the single technology: clinical information (clinical outcome, evidence based approach), technical (device data, workability, maintenance, security), economical and organizational (based on costs and impact on organization), ethical and social.

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Such evaluation is undoubtedly to be conducted before the introduction of a new technology and many models and approaches have been proposed through the years with different connotations, i.e. either more “policy-making” oriented [3] or more locally based, such as Hospital Based HTA or mini HTA from Denmark, although the latter shows some limitations [4], used when the evaluation considers a very localized situation.

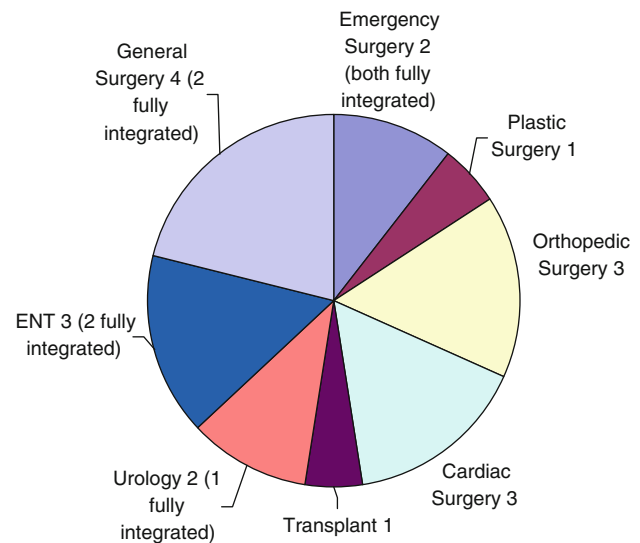
On the other hand, it might be useful to go through “follow-up” evaluations, especially in such cases where little literature is available due to recent introduction in the market or very limited access to technology.

The integrated operating room (OR), otherwise referred to as “digital OR” or “interventional suite”, is a technical solution mainly dedicated to minimally invasive surgery where environment (lights, climate, etc.), medical devices and video distribution are controlled via one or more PCs and activated via a single graphic interface [5]. In such an OR, each and every control is in surgeon’s reach, allowing him to interact and control the system using a boom-mounted, sterile touch screen that can be placed right on the operating field. A computerized video matrix controlled by the same touch screen distributes images to boom-mounted monitors thus allowing the best viewing angle to each operator [6]. Anyway, only solution granting video distribution and medical device control should be addressed to as “integrated OR” [7].

Vendors state that boom mounted devices, the possibility to view images on many displays that can be best fitted for the surgeon and surgeon’s direct device control connote the digital/integrated OR as a very efficient and effective environment, providing enhancement in flexibility and integration of information [8] with advantages for patients, OR workers and, in the end, for the hospital that buys the solution.

At the time being, there are many installations worldwide of such Integrated ORs which differ by vendor, degree of integration available, surgical specialty they are destined to, etc. Very little literature has been published on the subject, especially on system evaluation from an “operative” standpoint which is what defines the assessment of satisfaction of the solution adopted. It seems that the Integrated OR—in surgeons’ mind—is considered just a very nice technological solution, but it is not clear whether it is useful, effective and, in the end, worth the economical and organizational effort needed to implement it in a new or existing hospital.

In Varese Town and University Hospital 20 digital ORs have been recently built to fulfill the needs of 10 Surgical Specialties (Fig. 1). An evaluation inquiry to access the surgeons’ needs was conducted before building the ORs; results have been presented in previous works [9, 10] and were used to determine the correct OR configuration, whether they should be fully integrated (i.e. with medical device control) or should just have a digitalized video matrix installed to allow video routing. With this second configuration the imaging



**Fig. 1** OR distribution among surgical specialties. The number of integrated OR has been specified for each speciality indicating where the integration is full

distribution control can be performed using a multiple choice of monitors available as destination, i.e. one or more boom-mounted displays, a 40" plasma monitor on wall, a video-conference system, a DVD recorder or a centralized storage. Otherwise, when the OR is fully integrated, imaging distribution control is combined with medical device control as stated. Using the same sterile touch screen, either the nurse or the surgeon (or both) can activate and modify functioning parameters of CO<sub>2</sub> insufflator, pump, surgical camera and light source. Moreover, operating table position, environmental lights and DVD/CD player can be controlled. Three different products are installed and in regular use at the Varese Town and University Hospital: Karl Storz OR1<sup>®</sup>, Olympus Enodalpha<sup>®</sup> and Smith & Nephew Digital OR<sup>™</sup>. Figure 2 shows a fully integrated OR as installed in our institution.

## Objectives

Main objective of this paper is the evaluation of surgeons’ and staff nurses’ satisfaction and comments on the ORs that were installed in the new OR block of the Varese Town and University Hospital. Such evaluation was needed to figure out if the acquisition process results were correct and if expectations had been fulfilled or how they had been missed or over-considered. This results in an integrated OR solution qualitative study based on clinical staff opinion, which we considered the best parameter to be tested in order to have a valuable judgment of the solution implemented. Such evaluation is by all means needed by the entire scientific community due to the lack of literature on the subject. Data acquired in a



**Fig. 2** Picture of a fully integrated OR at the Varese Town and University Hospital

very limited and specific environment or institution represent a good set of data for a pilot study, in order to assess the completeness of the questionnaire needed for a wider study on the subject.

## Methods

A multiple answer questionnaire was handed to surgeons and scrub nurses. A total of 17 surgeons and 9 scrub nurses were interviewed. Interviewed people were selected among fully integrated OR users only in order to allow a complete evaluation, especially on the device control integration. Moreover, surgeons and scrub nurses have been judged the real direct users, while other OR operators like anesthesiologists have been classified as indirect users. They can in fact monitor patient parameters displayed through integrated OR system but they still need to directly interact with the ventilator and the patient monitoring system while they have little interaction with both video distribution and medical device control system.

Table 1 resumes interviewed staff level of experience and affiliation. Surgeons group is composed by experienced subjects working inside the integrated ORs from the installation date. Scrub nurses' level of experience resulted lower due to the frequent replacement which is a phenomenon that affects our hospital, where scrub nurses reside for a short time before moving to other hospitals or Switzerland.

Surgeons and scrub nurses were selected mainly from General Surgery (Table 1) because in our hospital there are two General Surgery divisions that work in five fully integrated ORs performing a great number of interventions. Fewer interventions are carried out by other specialties (Orthopedics, Urology and ENT) which nevertheless take advantages from the use of an integrated OR.

**Table 1** Interviewed population divided into two groups (Surgeons and Scrub nurses)

Specialty	Exp. years	Years in Varese
<i>Surgeons</i>		
G. Surgery	30	>6
G. Surgery	14	>6
G. Surgery	9	>6
G. Surgery	10	>6
G. Surgery	34	>6
G. Surgery	20	>6
G. Surgery	25	< 6 >4
G. Surgery	14	>6
G. Surgery	40	>6
Thoracic	30	>6
Orthopedic	27	>6
Orthopedic	20	>6
Orthopedic	20	>6
Orthopedic	12	>6
Urology	30	>6
Urology	25	>6
ENT	26	< 6 >6
<i>Scrub nurses</i>		
G. Surgery	1	< 6 >2
G. Surgery	7	< 6 >2
G. Surgery	2	< 6 >2
G. Surgery	10	>6
G. Surgery	3	< 6 >4
G. Surgery	5	< 6 >6
ENT	1	< 6 >2
Neurosurgery	5	< 6 >2
Urology	17	>6

For each subject, the experience level and the speciality has been specified. (G. Surgery stands for General Surgery)

Surgeons and scrub nurses belong to different surgical specialties and use different products since digital ORs from three different vendors are installed, as referred earlier. To some extent, this makes answers more general with regard to use of the OR and vendor preference.

The questionnaire used for scrub nurses is slightly different from the surgeons' one, but there are some common questions (Table 2). These are those we refer to in this paper. Such common questions made it possible for us to evaluate also the different profession's approach to the digital OR.

"Multiple guided answer" questions were proposed; the interviewed had to define a level of importance by distributing 100 points among the available options.

Questionnaires were answered with the interviewer present; this helped in question detailed comprehension, thus resulting in a more reliable answer.

**Table 2** Selection of questions from Questionnaire proposed in Varese Hospital to Surgeons and Scrub nurses after 2 years of experience

## Questionnaire for integrated OR technology evaluation—Varese Hospital

- 1 If compared with previous technologies, the integrated OR improves the following performances (distribute 100 points):
  - reduce risk related with surgical act
  - allow a better communication between surgeon and nurse
  - reduce hospitalization period for patient
  - reduce patient rehabilitation
  - increase the quality of patient treatment
  - reduce stress (fatigue) derived from intervention
  - reduce surgery time
  - others
- 2 In which of the following phases the integrated OR reduces surgical time (distribute 100 points)?
  - surgery scheduling
  - devices set up
  - patient preparation
  - anesthesia
  - surgical act
  - awakening
  - administrative phase
- 3 Assign a value (100 points in total) for each technology employed in integrated OR, considering its importance and utility during surgery:
  - boom-mounted devices
  - availability of more than one display
  - digital acquisition and distribution of images
  - integrated devices control
  - external camera for video-conference
  - others
- 4 The medical device integrated control has to be considered useful for the following reasons (distribute 100 points):
  - allow a better reactivity for urgent decisions help in diminishing setting errors
  - decrease mess while managing devices
  - provoke curiosity
  - reduce waiting time for materials
  - promote a reduction in staff displacements
  - reduce surgery time
  - there is no interest about this topic
  - there is no time to approach this topic
  - there is a lack of education about this topic
  - others
- 5 Why do you think learning can be facilitated by using integrated OR (distribute 100 points)?
  - reduction in learning time
  - there are more interventions available for learners
  - intervention can be approached from a better point of view
  - others
- 6 Please state the main issues still related with integrated OR use that need further development based on your experience after these years (distribute 100 points)
  - staff education
  - devices integration
  - the system demonstrated little usability
  - there are legal issues
  - the right cultural approach is difficult to be found
  - coordination between surgeons and the rest of the staff

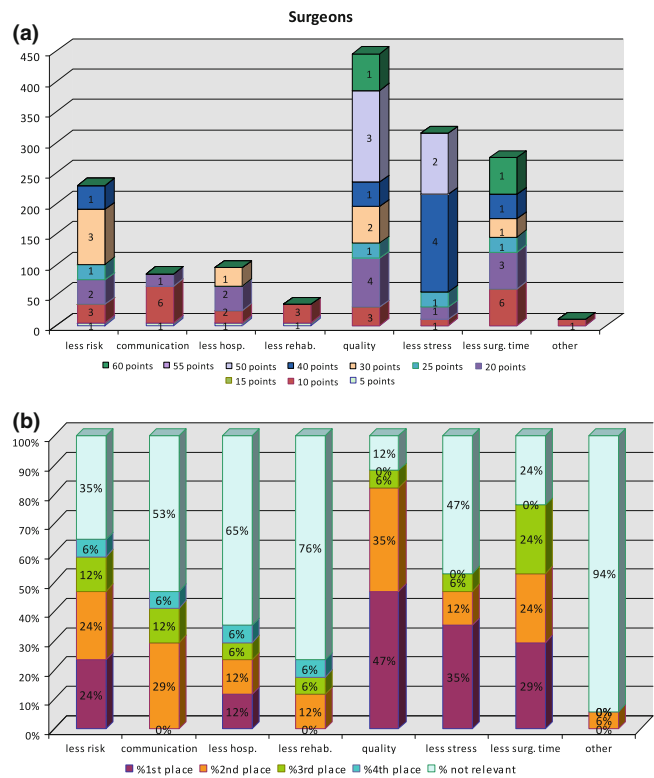
**Table 2** Continued

Questionnaire for integrated OR technology evaluation—Varese Hospital

- technology is not reliable
- financial sources are not available to sustain the costs
- others

The questions are those used to obtain the presented results

**Fig. 3** Surgeons’ answer distribution for 1st question: which performances are improved by integrated OR? Graphic (a) represents the absolute scores for each choice divided in colored blocks representing points distribution. Inside the block, the number of subjects that assigned that single value of points is reported. Graphic (b) shows the distribution of surgeons’ percentage for each choice in terms of place classification



**Results**

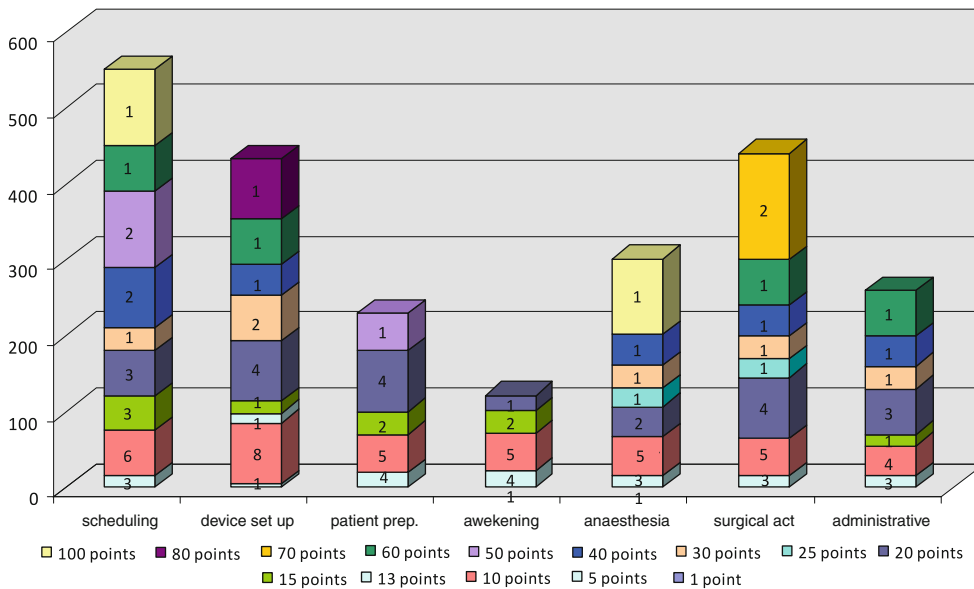
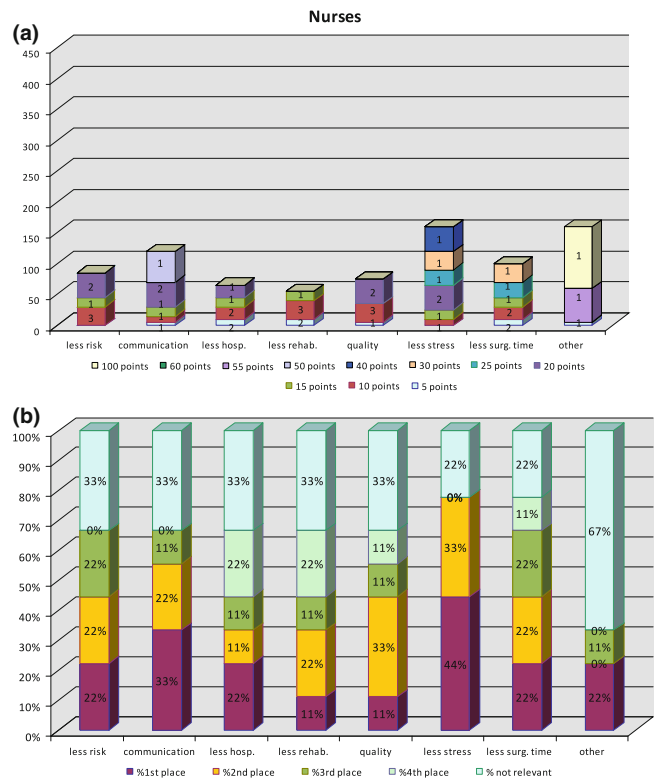
The aim of our first question was to test the usefulness of integrated OR. Options available ranged from reduction of patient risk to hospitalization time, rehabilitation, quality of surgery, surgical stress, surgery time. Figures 3 and 4 present the results separately for the two interviewed groups. Enhanced quality of the surgical act has been classified as the best option in terms of total reached scores (520 points). The second best choice to be selected was stress reduction (475 points total), followed by reduction in surgical time (375 points total). It’s interesting to read the same data in terms of classification (Figs. 3 and 4, graphics b)). In fact quality of surgery has been chosen as best option by 47% of surgeons vs only 11% of scrub nurses, while 35% of surgeons rank it as 2nd option, resulting in an overall 82% of surgeons stating that the integrated OR augments quality. It must be noted that three surgeons gave 50 points to such aspect and one 60,

making us assume that the chosen option is really relevant to them. No 5th and 6th place was assigned mainly because interviewed people distributed available points among four options only. Both surgeons and scrub nurses agree that the integrated OR can reduce stress related to intervention (35% of surgeons and 44% of scrub nurses chose this as best option) and reduce surgery time (29% of surgeons rank it as 1st, 24% as 2nd and 24% as 3rd, 22% of scrub nurses rank it as 1st, 2nd and 3rd).

The fact that integrated OR can reduce risk related to surgery has been voted with 315 points, and obtained a total (1st and 2nd place considered together) percentage equal to 48 and 44% of surgeons and scrub nurses, respectively.

In order to go in to more details about the noticed reduction of surgical time, a specific question (second question) was proposed on this topic. At first place, the results (Fig. 5) show a time reduction especially in surgery scheduling phase. Then staff has the impression that surgical act duration and devices

**Fig. 4** Scrub nurses' answer distribution for 1st question: which performances are improved by integrated OR? Graphic (a) represents the absolute scores for each choice divided in colored blocks representing points' distribution. Inside the block, the number of subjects that assigned that single value of points is reported. Graphic (b) shows the distribution of surgeons' percentage for each choice in terms of place classification



**Fig. 5** Answer distribution for 2nd question: evaluation of time reduction due to integrated OR. Different phases have been identified and voted. Absolute scores are presented for each phase divided in colored

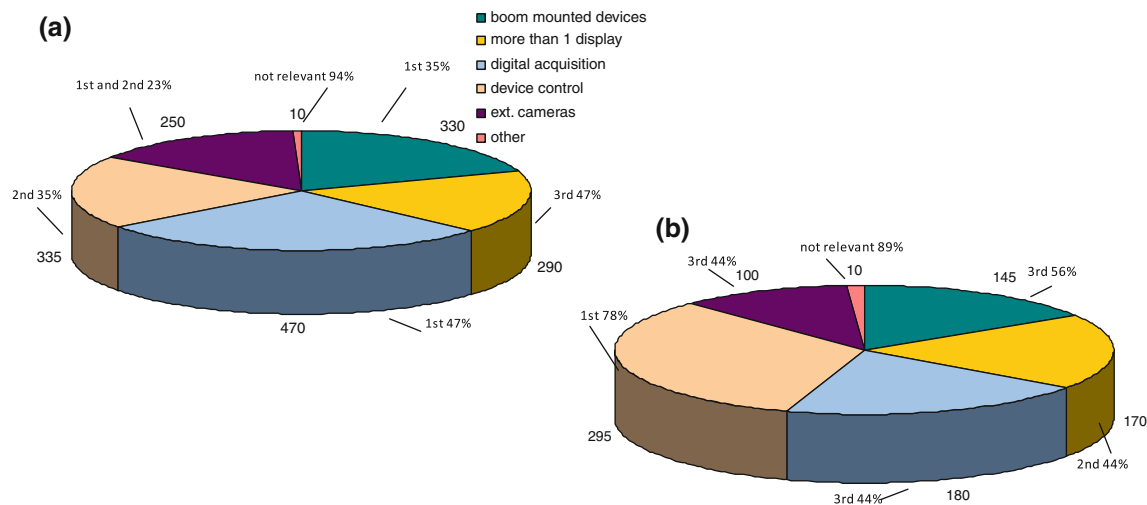
blocks representing points distribution. Inside the block the number of subjects that assigned that single value of points is reported. Results have been presented together for Surgeons and Scrub nurses

set up phase has been reduced. Scrub nurses in particular stressed the point that also anesthesia preparation procedure became shorter due to the integrated OR facilities.

Even while evaluating the automatic presetting functions, i.e. such tool that allows to store in the system functional parameters for each device and surgeon and/or dedicated pro-

cedure set up, surgeons and scrub nurses substantially agree that this function could first of all reduce the theater preparation time (53% of surgeons and 67% of scrub nurses). This observation confirms again the general impression that procedure time is significantly reduced with integrated OR use.





**Fig. 6** Answer distribution for 3rd question: classify each technology employed in integrated OR, presented separately (**a** surgeons, **b** scrub nurses). Near each values indicating the total score obtained by each option the highest ranking expressed in percentage has been annotated

OR layout was then analyzed (third question) to evaluate available functions such as the usefulness of computerized video matrix for images acquisition and distribution, the control system use, the utility of mounting devices (endoscopic camera, light source, CO<sub>2</sub> insufflator, electrosurgical unit) on a single boom and the possibility to orient more than one display on independent boom arms. Results have been summarized and represented with two graphics (Fig. 6) that synthetically show which option might be mostly welcome during a surgical intervention. 47% of surgeons rank video acquisition and distribution most important (1st place, and a total score equal to 470 points). On the contrary, 78% of scrub nurses rank device control in first place with a total assigned score of 295 points. There is a different judgment about the need for boom-mounted devices, which has been voted with 330 points by surgeons (35% of surgeons rank it in 1st place and 29% in 2nd) and with 145 points by scrub nurses (mainly ranked as 3rd place). The judgment on the availability of more than one display is comparable.

As far as medical device control is concerned (fourth question), options ranked from increased reactivity to events, reduced setting errors, reduced confusion, reduced displacements of devices and monitors. Figure 7 presents total absolute scores for each option since the classification trend is similar for Surgeons' and Scrub nurses' values. First, both Surgeons and scrub nurses stated that direct control can grant better reactivity to events that occur during surgery. This point was particularly emphasized by scrub nurses.

On the other hand, both surgeons and scrub nurses observed that such a system can reduce device setting errors (surgeons a little more than scrub nurses—35% as 1st place vs. 22%). Moreover, it has been noticed that device control implemented inside integrated OR can reduce mess and racket and the number of displacements of devices, monitors

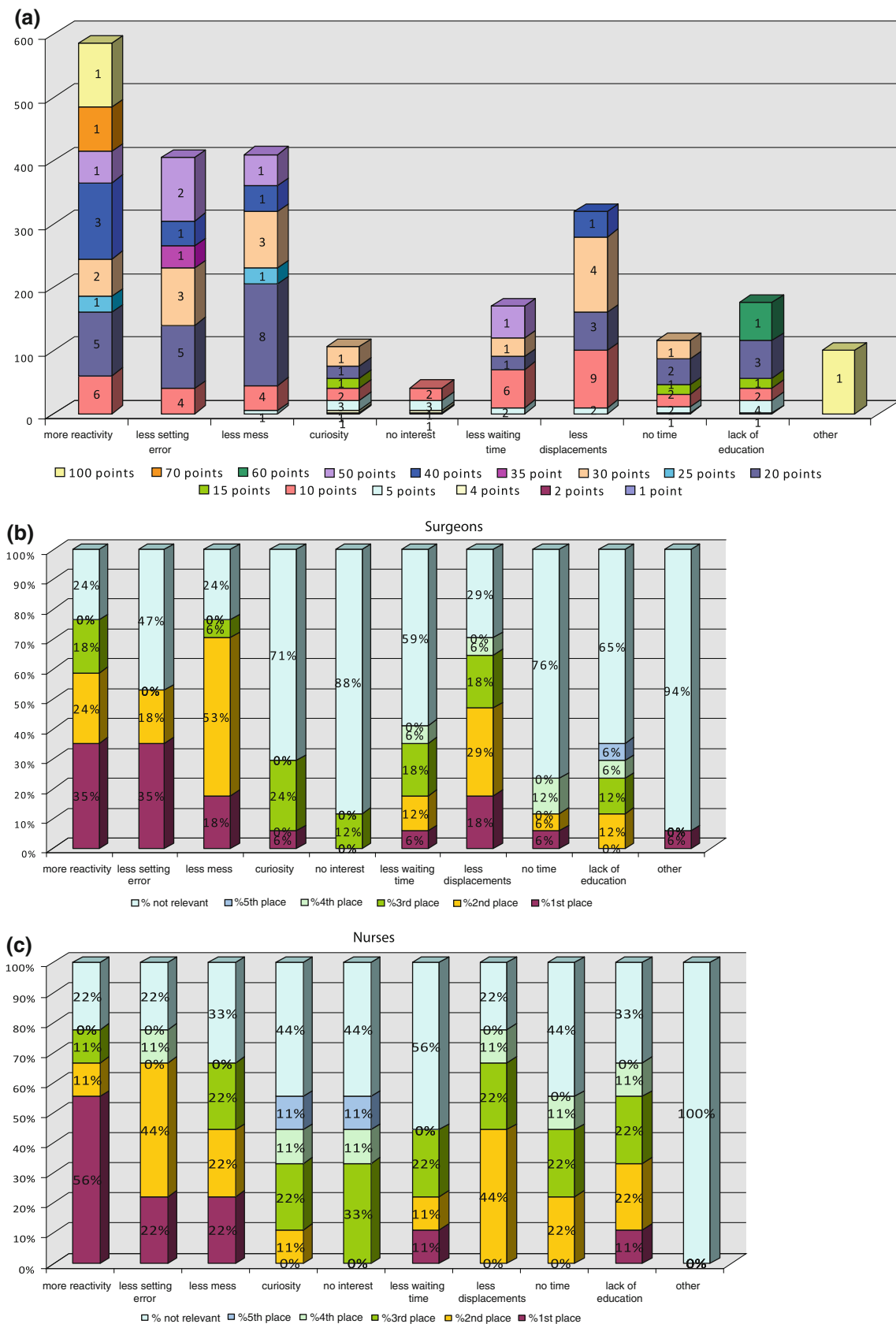
etc. during surgery although scrub nurses do not consider this aspect as most relevant (1st place: 0%).

We tried also to focus on the teaching capabilities of the integrated OR (fifth question). The majority of surgeons think that this installation could grant significant advantages in the teaching progress and organization as shown in Fig. 8. 76% of surgeons, in fact, think primarily that a better “point of view” on the surgical field can be achieved and then that a higher amount of surgeries could be viewed. A similar judgment came from scrub nurses that moreover estimated relevant the chance to have more interventions available for learners.

At the end, when asked to evaluate the problems that were still unsolved (sixth question), surgeons and scrub nurses agree that there is first of all a need for education (Figs. 9 and 10). Then nurses evaluated as a relevant problem the lack of integration of specific medical devices (i.e. ultrasonic scalpels, electrosurgical units) and think that there is a significant cultural problem when approaching such technology. Instead surgeons are more concerned about coordination and reliability of the technology.

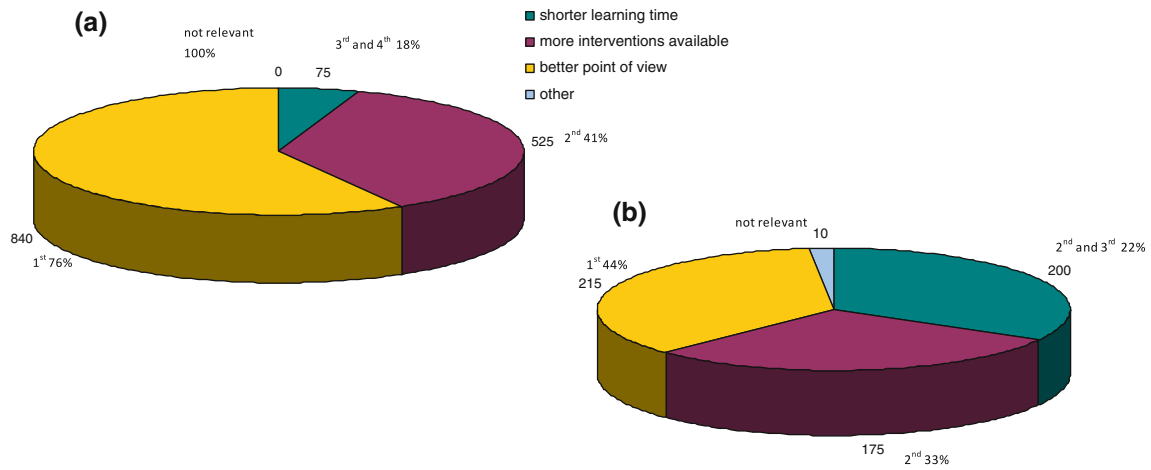
## Conclusions and discussion

The results of the questionnaire show a substantial satisfaction by both surgeons and scrub nurses, given that the installed technology grants multiple advantages to workers and patients. Among such advantages, we can enumerate increased quality of patient treatment and reduced stress during surgical act (Figs. 3 and 4), reduced time for device setup and surgical act (Fig. 5), increased reactivity for urgent decisions and reduced setting errors and racket (Fig. 7). Such advantages are mainly obtained using features of the integrated OR such as video acquisition and distribution and

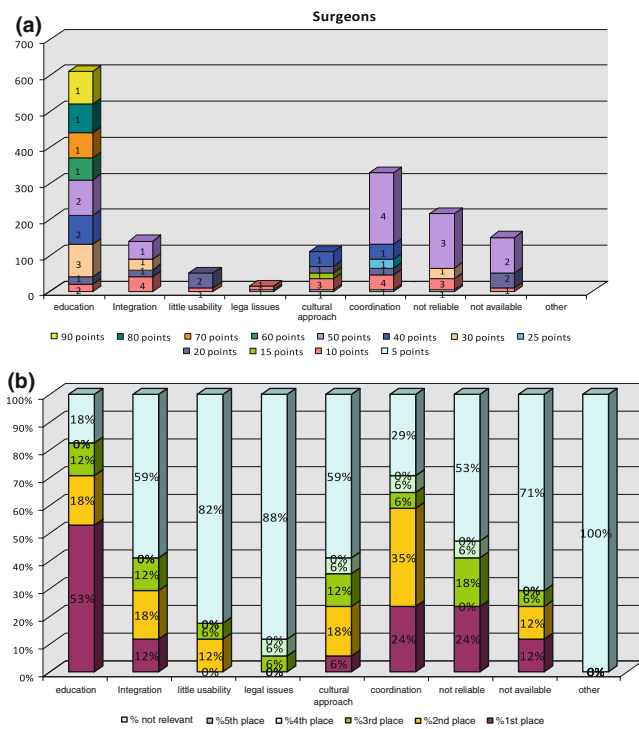


**Fig. 7** Answer distribution for 4th question: utility of device control. Total scores are presented (a since both surgeons and nurses agreed. Two graphics representing ranking expressed in percentage, b surgeons, c scrub nurses) follow

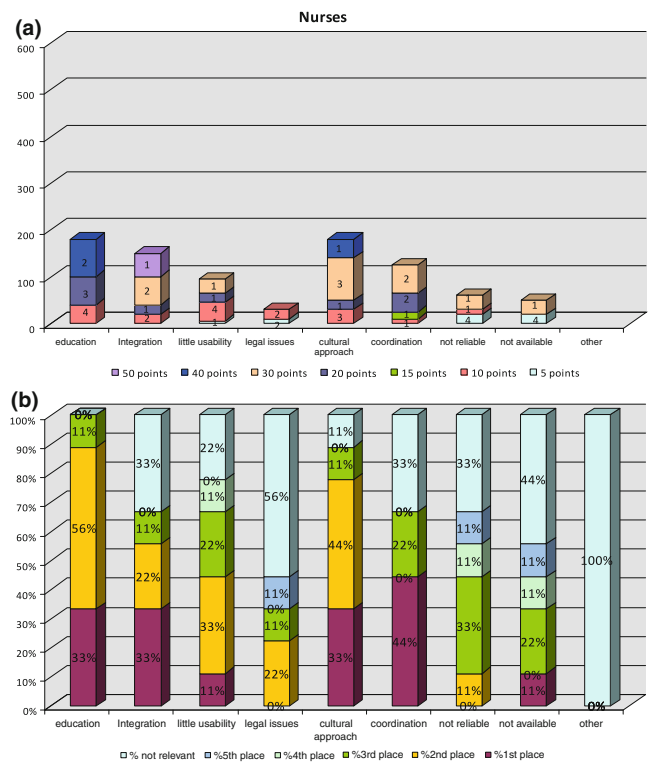




**Fig. 8** Answer distribution for 5th question: teaching capability in integrated OR, presented separately (**a** surgeons, **b** scrub nurses). Near each values indicating the total score obtained by each option the highest ranking expressed in percentage has been annotated



**Fig. 9** Surgeons’ answer distribution for 6th question: problems unsolved related with integrated OR. Graphic (a) the absolute scores for each choice divided in colored blocks representing points distribution. Inside the block the number of subjects that assigned that single value of points is reported. Graphic (b) for each choice distribution of surgeons’ percentage in terms of place classification

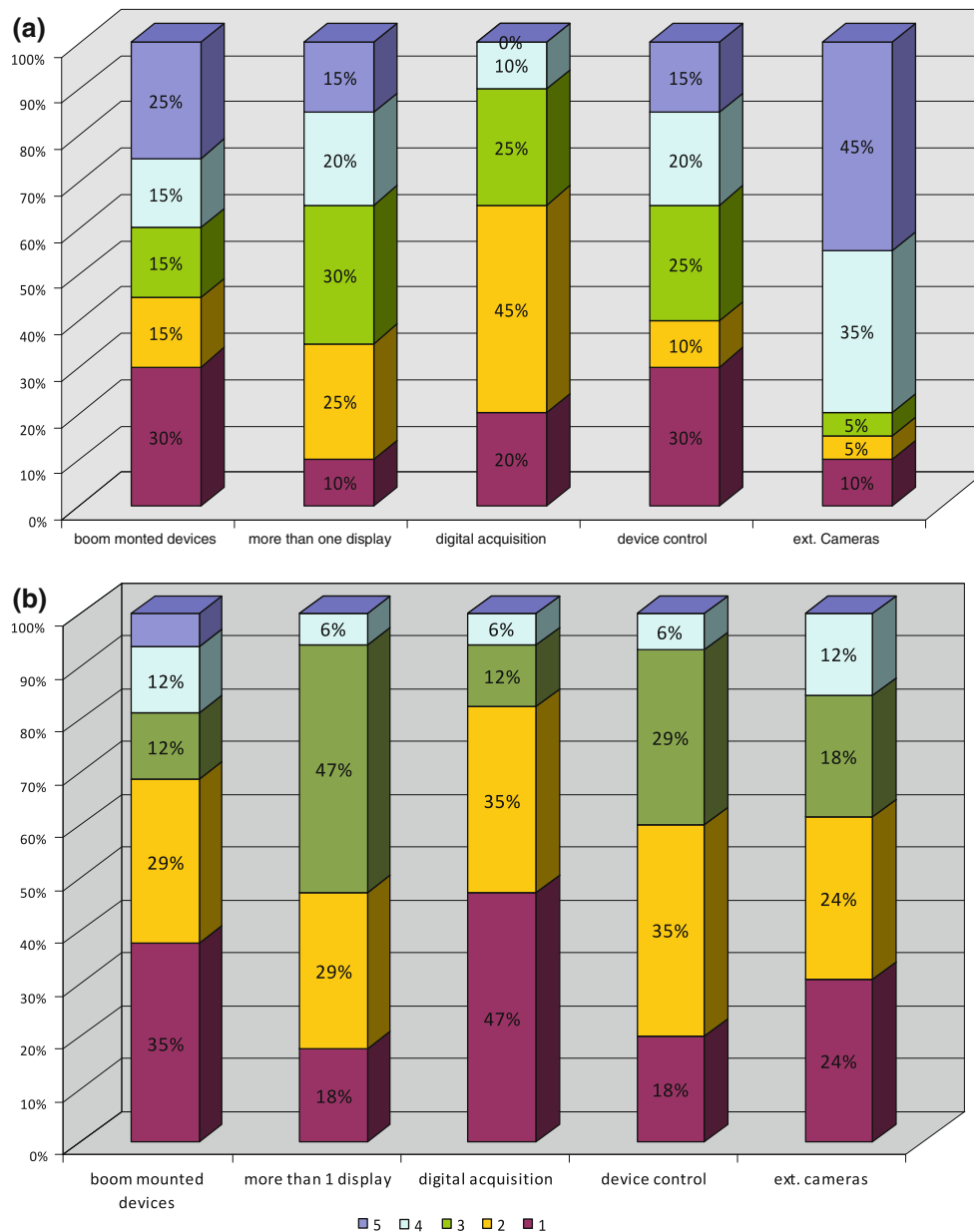


**Fig. 10** Scrub nurses’ answer distribution for 6th question: problems unsolved related with integrated OR. Graphic (a) the absolute scores for each choice divided in colored blocks representing points distribution. Inside the block the number of subjects that assigned that single value of points is reported. Graphic (b) for each choice distribution of surgeons’ percentage in terms of place classification

medical device control (Fig. 6). The use of medical device control and availability of different types of information can improve security and efficiency of the surgical act, as stated by other authors [8].

It must be pointed out that most of the results are similar to those obtained from the first questionnaire [9], and

in few cases only were changed substantially. Only 20% of surgeons ranked as first option, the availability of a digitalized image acquisition and distribution system when they had been asked to place the more desirable integrated OR feature before installation while in the present work it



**Fig. 11** Before integrated OR installation, surgeons and scrub nurses had been asked to classify (1st, 2nd, 3rd, 4th, 5th place) a list of desirable solutions implemented (boom-mounted devices, more than one display,

digital acquisition, device control, external cameras). Results are presented in terms of percentage (a) and compared with results obtained for the same question, (b) during the second interview

has become 47% (Fig. 11). Before setting these ORs into service, the majority of surgeons thought these systems to be less effective in error reduction and reactivity to unexpected events (Fig. 12).

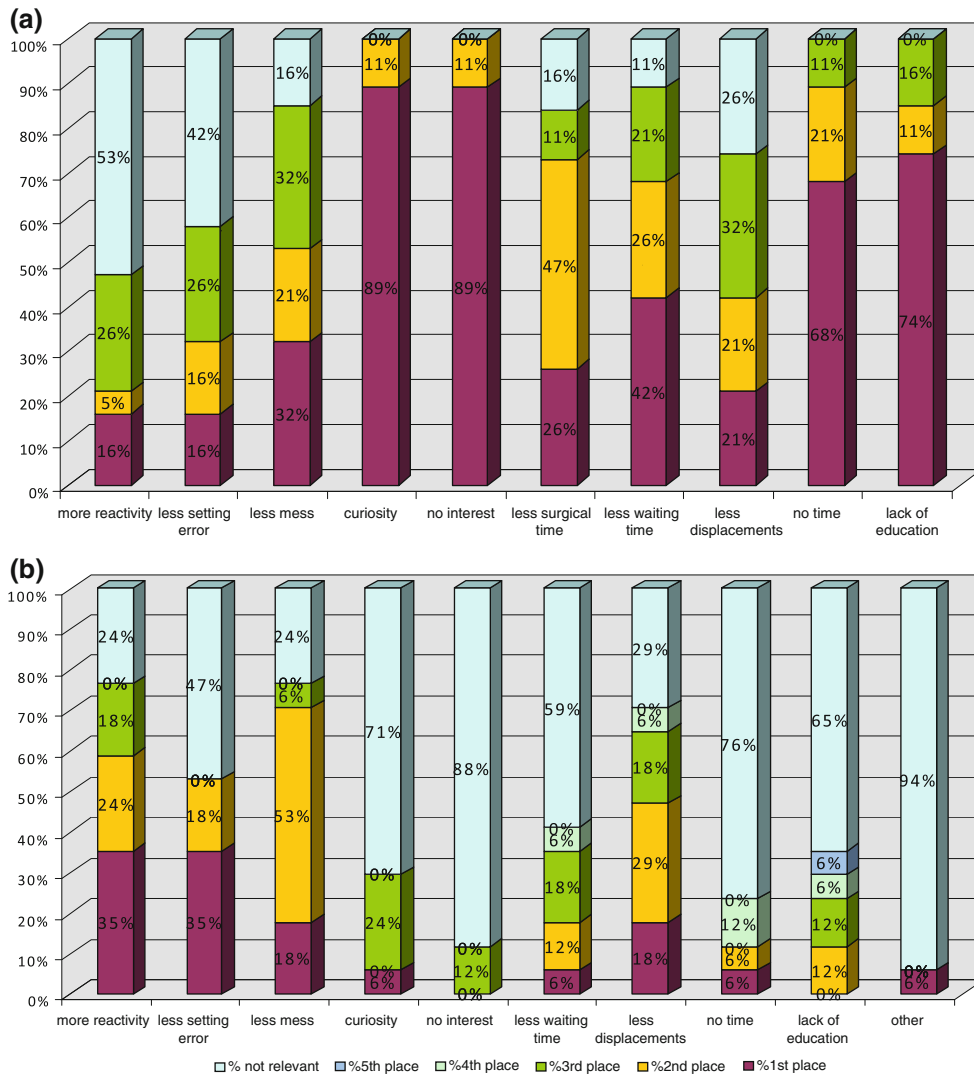
Moreover, previously 30% of surgeons thought medical device control was one of the most important solutions to be implemented (Fig. 11), and this percentage dropped to 18% in the present work.

In any case, the results mean that what was acquired and built in the new OR block of the Varese Town and University

Hospital fulfilled the surgeons' and scrub nurses' need, both on the technological and organizational point of view.

In fact, the main conclusions derived from results, while considering the data as a post-installation impact, are that a relevant improvement in quality has been introduced with integrated OR and a less stressing and shorter surgical procedure has been achieved.

Moreover, the results presented earlier can help the reader face the different approach to technology between surgeons and scrub nurses, the latter being more concerned about



**Fig. 12** Before integrated OR installation, surgeons and scrub nurses had been asked to classify (1st, 2nd, 3rd, 4th place) a list of aspects and expectations related to the installation. Results are presented in terms of

percentage (a) and compared with results obtained for the same question, (b) during the second interview

workflow and surgical process in general. This is confirmed by answers given to the question concerning layout (where little interested was reserved to video acquisition) and to utility of medical device control and presetting. Surgeons appear to be more concentrated on surgical act itself; such conclusion is endorsed by the ranking given to availability of images from surgery, reduced surgery time and increased quality (Fig. 3) rather than device control, setting error or process standardization. Anyway, results shown outline that it is clear that the Integrated OR can help overcome the usual problem of modern ORs, i.e. a conspicuous presence of high tech devices with little care to ergonomics of the OR itself [11].

The same results make us confirm other finds of a previous work [10] and in particular the fact that the integrated OR is a valuable investment, i.e. such an investment that, although

expensive, enhances the quality of performance through augmented possibility for all the people working in the surgical theater. Especially, the perception of a decreased surgical time, together with a sensible reduction of the waiting time, can be considered a data supporting that the integrated OR installation is responsible for a long-term economical save. Objective data about surgical time, hospitalization time reduction and patient quality scores (easily accessible using a HIS or specific software) are not available in or institution at the time being. This fact doesn't allow us to compare the perception transferred in the answers and real data, thus confirming or disproving the data presented.

The assessment of teaching capabilities (Fig. 7) is comparable to those obtained by other authors, especially when referring to availability of viewable interventions [12]

and assess simulation to prepare nurses before entering the theater [13].

An unexpected but very interesting result was obtained: both surgeons and scrub nurses think that many functionalities available in an Integrated OR could help reduce clinical risk for patients, as stated in other works [8]. If confirmed, such answer will add even more “value” to the Integrated OR solution, while showing the personnel’s awareness for this kind of problems. At the same time, risk reduction can impact on complication occurrences which comport also a high cost.

Data presented make us state that the integrated OR is a technical solution that should be evaluated by each institution that wants to enhance its healing capabilities and its organizational structure. The great need for education, cultural approach and coordination between surgeons and scrub nurses (Figs. 9 and 10), with related costs, can be used as other drivers to define if the solution is to be acquired or not.

More work is to be done on the subject. The questionnaire seems to be useful and could be submitted to a wider population of surgeons and scrub nurses using integrated OR to reinforce the data available and design a statistical validation of the answers.

Nevertheless, it has to be integrated with objective quality and performance indicators, such as surgical timings, hospitalization time, number of procedures per year pre and post-installation. Such data should be helpful in confirming the assessment obtained.

Moreover, it is important to point out that, since the integrated OR is a quite new technology, there is need for a deeper examination on topics like standardization of control protocols for medical devices in order to obtain a vendor-independent environment [14] and workflow standardization and integration in the clinical information system [15].

Also education of surgeons and scrub nurses on the advantages of such systems as substantial and literature-evident improvement in treatment, organization and, as direct consequence, economy, could help to impact on the users’ approach and then corroborate the thesis that it is a really valuable technology.

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