DECISION-MAKING WITH MULTIPLE CRITERIA IN THE SELECTION OF ULTRASONIC SCANNING SYSTEM IN A PRIVATE HOSPITAL IN BRAZIL

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ABSTRACT

This article presents the Analytical Hierarchy Process (AHP) as an aiding approach in decision-making, applied to the technical evaluation of the acquisition process of ultrasonic device in a private hospital in Brazil.

Some steps and principles of AHP, such as the complexity of hierarchical decomposition, comparative judgments, priorities synthesis, and sensitivity analysis show, themselves to be utilities for the success of the technical evaluation process, going from meeting the hospital's necessity for transparency to auditable process documentation.

The hospital's management's expectation of separating the hospital's medical technical evaluation process from the commercial evaluation process was achieved through the application of AHP. Despite the great number of possible variables for the ultra-sound's technical evaluation, the decision-making team adapted itself easily and quickly to the employed method, contributing to the success of the work.

The range of medical equipment installed in Brazil presents geographic concentration, with a large percentage of the equipment remaining unused due to lack of maintenance or inadequate staff to operate them, and the quantity of determined image devices per habitant above the average of other developed countries. That reality leads to the waste of resources in the health sector and adverse effects to the population's health. This confirms the pertinence of the instrument's application in this work, and

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indicates the potential increase in its utilization in the planning and control of public and private resources in the health sector.

Key-words: Health Technology Assessment, Medical Equipment, Analytical Hierarchy Process

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1. Introduction

Healthcare costs and the increasing cost of healthcare are public interest concerns in many countries (Lim *et. al*, 2009). The health sector suffers the effects of the world phenomenon called "medical inflation", which consists of medical service's tendency to increase its prices above general economic price indexes. Uncontrolled technological incorporation is one of the principal factors in the phenomenon's development.

This is the consequence of some biomedical technology characteristics, such as their accumulative and non-substitutive character. For example, Computed Tomography (CT) scanners don't substitute for Conventional Radiology (X-Rays) devices, but are used in addition to them. Furthermore, the intensive nature of the biomedical technology workforce contributes to this phenomenon of medical inflation, as it impedes or diminishes the economy of scale's gain in work force cost. This problem is also exacerbated by the fact that biomedical technology is disseminated with great velocity and, being incorporated precociously, many times without proving its efficiency (Mendes, 2006).

Developing countries are technologically dependent on developed countries, and import a great deal of medical equipment, especially high tech instruments. In the case of incorporating technologies without criteria, developing countries run the risk of importing systems designed for developed countries' epidemiological reality, instead of creating solutions for their own countries' problems.

The lack of concrete actions for the medical-hospital equipment incorporation's control and planning in Brazil, as well as the unawareness of this equipment's quantity and quality in the health network have led to a series of misrepresentations, such as high concentration of image equipment in closely-located sites, generating high complexity processing demands and high cost that are often unnecessary. For example, the city of Belo Horizonte in Brazil has a population similar to Paris, France; however, it has 8 times the installed CT scanners, despite dealing with endemic tropical diseases such as dengue, yellow fever and mansonic schistosomiasis, implying the inefficient utilization of the purchased equipment and lack of other, more necessary equipment (Nepp, 2000).

Along with this scenario, there is a growing awareness of the relationship between the medical and the pharmaceutical industries. It can reach the ethical limit of marketing investments, materializing in the form of gifts to physicians and its effects on their professional conduct with patients, including the induction and prescription of a determined medicine or execution of a certain procedure.

Similar phenomenon occurs in the medical equipment industry (Halperin, Hutchinson & Barrier, 2004; Collins, 2006). Therefore, the physicians responsible for the technical choice in the acquisition process can define the equipment to be acquired, basing the choice, principally, on their personal gains, in detriment to the interests of the hospital, which is purchasing the device.

Ramirez (2005) comments that a detailed evaluation in the moment of equipment acquisition is very important in order to avoid needlessly raising the cost of health services. Nevertheless, in Brazil for cultural reasons, the greatest preoccupation is concentrated in the execution of work and the medical equipment's purchase, and not to processes such as rational purchase planning, receipt and acceptance protocols, training, and maintenance, among others.

In this context, support instruments for decision-making, such as the Analytical Hierarchy Process (AHP), are indicated for the systemization of complex decisions in the health sector, with prioritization of projects and allocation of resources, among other uses, contributing to the decision's rationalization and reduction of wastes (Panerai & Mohr, 1990).

The present work describes the application of AHP in the technical evaluation process of medical device acquisition in a private Brazilian hospital, with the purpose of contributing to the process's rationalization and systemization and of generating auditable documentation of the criteria utilized to obtain the evaluated equipment's technical ranking. This will permit a more rational approach in choosing the commercial proposal winner.

The target support instrument for decision-making was brought into, unveiled and implanted in the hospital, which previously applied no formal or systemized methodology for the technical purchase evaluation of medical equipment. The absence of such an instrument had caused serious problems for this institution in the past, leading to the acquisition without criteria of very expensive imported medical equipment that contributed to the financial insolvency of the institution, which the Public Ministry considered closing.

The institution's managers searched for management tools which gave transparency to the medical equipment acquisition process, and permitted its audit, expecting that they could reduce ethical miscues in the evaluation process, and reduce the risk of repeating past errors.

The methodology used in the work is an action-research in which an empirically-based qualitative and quantitative focus is conceived and carried out in strict association with an action or with a resolution of a collective problem and in which the problem's researchers and participants are involved in a cooperative or participative manner (Brandão, 1999).

2. Diagnostic ultrasonic scanning system

Presently, the diagnostic ultrasonic exam is the most used diagnostic imaging method in clinical use, making up about 25% of all image studies realized in the world (Forsbeg, 2004). It is one of the most rapidly growing means of image obtainment in the number of exams realized in the entire world. Such growth, among other factors, is owed to the low cost of the exam, real time interactions and its apparent lack of adverse bioeffects (Rumack, Wilson & Charboneau, 1999) and, also, for being a non-invasive method and not utilizing ionizing radiation, such as Conventional Radiology and Computed Tomography (Andreassi, Venneri and Picano, 2007).

Typical ultrasonic equipment model can be acquired from many manufacturers offering devices that increase modularly in sophistication, resources and price, which can go from US$ 20,000 to more than US$ 300,000, depending on the configuration.

In general, the ultrasound equipment possesses a modular design that permits future updates and upgrades, including specialized functions, such as Doppler cardiac imaging and harmonic tissue imaging, (ECRI, 2005).

Standard ultrasonic scanning system consists of an electrical pulse generation and transmission unit to excite the transducers, a reception and amplification unit for the captured signals, a control and processing unit to configure the emission and reception parameters, and a unit to visualize the process's resulting image in one or more monitors. It sums up to this: a set of transducers, an interface with an operator, an energy source and some recording devices (ECRI, 2005).

As a consequence of the device's large market, the medical equipment's industries that produce the ultrasonic scanning system have invested in the development of new technologies that increase the image's diagnostic capacity. Such technologies are put on the market under many different commercial names by the industries, as a marketing strategy to show competitive advantage over the competition, in spite of conceptually dealing with the same technical resources. This results in confusion for the purchaser and the final user. A multicriteria decision approach can rationalize this comparison and avoid waste and unnecessary expenditure.

3. The Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) developed by mathematician Thomas Lorie Saaty is the most used Multi-criteria Decision-Making Method probably due to its ease of application.

Saaty (1987) comments that the AHP theory was developed in 1972 to solve a specific contingency planning problem and later, in 1977, an application of greater visibility: the projection of future alternatives for the developing country of Sudan. Since then, the ideas developed progressively through its applications in various other projects.

Forman (2001) comments that the theory's application in 1983 in computer program Expert Choice, caused a rapid growth of the number, the diversity and the complexity of AHP applications. Thousands of articles about AHP application have been published in scientific journals (Ho, Xu and Dey, 2010), many of which are related to the health area (Lettieri and Masella 2009; Liberatore and Nydick, 2008; Wu, Lin and Chen, 2007; Sloane *et. al*, 2003). AHP is perhaps the most used decision support method in the literature for selection of suppliers (Van Der Rhee, Verma and Plaschka, 2009).

AHP has been used in applications for governmental organizations and for private businesses, some of which institutionalized its use, such as the United States Departments of Defense and Energy, and the Xerox Corporation (Saaty, 1994).

The pairwise judgments phase based in a scale of reason permits the decision-maker to use objective considerations (concrete facts and knowledge) and subjective considerations (intuition, creativity, personal experience and insight) in a logical path. The utilization of a scale of reason makes analysis of tangible and intangible variables possible. On the other hand, this phase incorporates redundancy of judgments of one element in relation to the other and vice-versa, which in turn reduces the errors of measurement or judgment and permits the production of the judgment's consistency measurement. The method supports a certain level of inconsistency in the judgments elaborated by the decision-maker, as is with human beings. Still, it supplies a measure of the judgment's consistency, and a limit from which they should be reviewed (Forman, 2001).

4. Case study

The Mário Penna Foundation (FMP), headquartered in Belo Horizonte, is the largest provider of chemotherapy and radiotherapy services in the State of Minas Gerais, and one of the 10 largest oncologic centers in Brazil. FMP maintains two hospital units in Belo Horizonte the Mário Penna Hospital and the Luxemburgo Hospital.

In 2006, the Luxemburgo Hospital, site of the application of this work, possessed 190 beds, of which 20 were in the ICU – Intensive Care Unit, 6 surgical rooms and the largest radiotherapy service in Minas Gerais. Its annual production consists of 12,000 admittances, 5,300 surgeries, 18,000 chemotherapy sessions, 90,000 radiotherapy sessions and 290,000 laboratory exams.

Luxemburgo Hospital is a high complexity general hospital focusing in four areas: Oncology, and its medical support specialties: Cardiology, Hemodynamic and Neurosurgery. The hospital needed to purchase an ultrasonic scanner with color Doppler and endovaginal and endorectal capabilities so that the institution remains a High Complexity Center, according to the legislation at the time.

As the evaluation for the acquisition of new ultrasonic equipment began, a different purchasing structure was proposed to the FMP superintendent, with AHP application for the technical evaluation and ranking of the equipment under consideration. It was immediately accepted .

The purpose was to avoid the Institution's previous experiences of acquisition without criteria of medical equipment, which contributed to the near financial insolvency of the institution, and to give transparency and an audit trail to the process.

4.1 Purchase process structure

The necessity to purchase a new ultrasonic scanner made the application of AHP possible in the technical evaluation process. Such equipment possesses a great number of technical characteristics that must be evaluated and, according to ECRI (2004), the brand and model alternatives offered by the principal manufacturers are very similar one to another, in relation to quality and performance.

The evaluation technique was structured as one of six subprojects within the Ultrasonic Scanning System Acquisition Process. This paper shows the subproject of technical evaluation.

The technical evaluation was the AHP application's target, and was performed by the Luxemburgo Hospital Ultrasonic Service Medical Team. The process of technical evaluation consisted of the following roles and agents:

1. Decision-makers: responsible for the ratification of the technical decision and assuming its consequences (Gomes, Gomes and Almeida, 2002). In this work the role was exercised by two physician representatives of the Luxemburgo Hospital Ultrasound Service Medical Team.

2. Facilitator: responsible for clarifying and modeling the process of evaluation, focusing the solution of the problem, coordinating the point of view of the decision-makers, keeping them motivated and highlighting the learning in the decision process. This agent must have experience in the decision process and maintain a neutral position in order to not intervene in the judgment of the decision-makers (Gomes, Gomes and Almeida, 2002). That role was exercised by one of the paper's authors.

3. Analyst: responsible for aiding the decision-makers and the facilitator in the problem structure and in the identification of factors that influence the evolution, solution and configuration of the problem. That role was exercised by the person responsible for the purchasing department and the one responsible for the legal department.

4.2 The construction of the hierarchy

A sketch of the initial hierarchy was assembled based on the literature's data, supplied by ECRI (2004); Kolzer *et. al*, (2002), and free suggestions from the decision-makers and analysts.

The first level of decision hierarchy, after the goal, was extracted from the suggestion of ECRI (2004). It purged the cost of the item as not being the target of the technical evaluation, but of the Commercial Evaluation. Still, the initial quantity of criteria was very large, averaging out to 115 items to be evaluated later in a pairwise fashion.

By using a consensus, an effort was made to reduce the number of criteria to avoid criteria that weren't very expressive or were redundant, facilitating the elaboration of the weights and judgments, facilitating the elaboration of the purchase requisition order, and facilitating the verification of the equipment criteria.

The professional experience of the deciding physicians indicated ECRI's same sentiment (2004): there are not distinct differences in the products' ultimate function, producing ultrasonic imagery, between the similar manufacturers' models. On the other hand, it was decided that the analysis would be qualitative, keeping in mind, that the Luxemburgo Hospital and the medical equipment companies in Belo Horizonte don't have devices available, such as phantom, for quantitative comparison and verification of the transducer's quality parameters. The principal criterion would be the transducer's performance evaluation, in each image's modality, in the sense of producing an image with diagnostic quality from the physician's point of view.

Concurrently, the criteria that wouldn't have the possibility of being confirmed were purged, including the time for the problem's solution and the time of arrival to the client after solicitation of the local manufacturer. This decision was made considering that other hospitals would possibly be visited to have equipment installed, and they didn't make a systematic or historic control of these maintenance parameters in their clinical engineering.

The rationalization effort resulted in a hierarchical structure with 35 criteria and subcriteria under the goal. Among these, 27 criteria were the targets of direct comparison between the alternatives, considered most relevant and with the least probability of being redundant or of having the same weight or judgment value with pairwise alternative equipment comparison available on the market. Thus, the hierarchical decision structure was concentrated as shown in Figure 1.

These criteria form the base of the purchase requisition order, and were the evaluated items in the visits to other hospitals and in the devices' demonstrations by the manufacturers or its distributors in the Luxemburgo Hospital. Next, the deciding physicians made a definition of the local weights for each group and subgroup of criteria, as shown in Figure 2. During the judgments the weights were attributed through consensus by all the decision-makers. The overall calculated inconsistency was 0.02, and then the results were considered acceptable. The program Expert Choice, version 11, was used for the calculations. To illustrate the judgments made by the decision-makers, Figure 3 shows the matrix used to calculate the weights of the main criteria. In this case, the inconsistency was 0.03, and also the results were considered acceptable. All the others judgments were made using the same approach.

In the first level, the item that obtained by far the most weight was the criterion "Functions and Features" with 0.568, being considered more important than all the other criteria combined (ease in use, image storage and documentation, and customer support). This is due to three understandings on part of the decision-makers:

The ultrasonic equipment, in general, doesn't incur many maintenance problems;
The decision-makers use many equipment models, as they already work in other ultrasonic services, the learning of one more equipment or program's functionality or interface was not a problem;
The archiving is a final process, and does not contribute directly to the diagnostic result.

In the "Functions and Features" node, the subcriterion with the most weight was the "convex probe" with 0.648, followed by the "linear probe" and the "endocavity probe". The "convex probe" is the most used probe to practice medicine by the physicians in the general clinic, and that is the reason for it having the greater weight. The "linear probe" is most used to examine children and the "endocavity probe" is used in gynecology.

For each probe, second level criterion, the most important subcriterion was "performance with B mode", image modality most utilized in practice, followed by subcriterion "multi-frequency image", indicative of the axial resolution and achievable field depth with the probe. The image resources in the "color and power Doppler" mode and the "harmonic image" are less utilized in day-to-day hospital oncology.

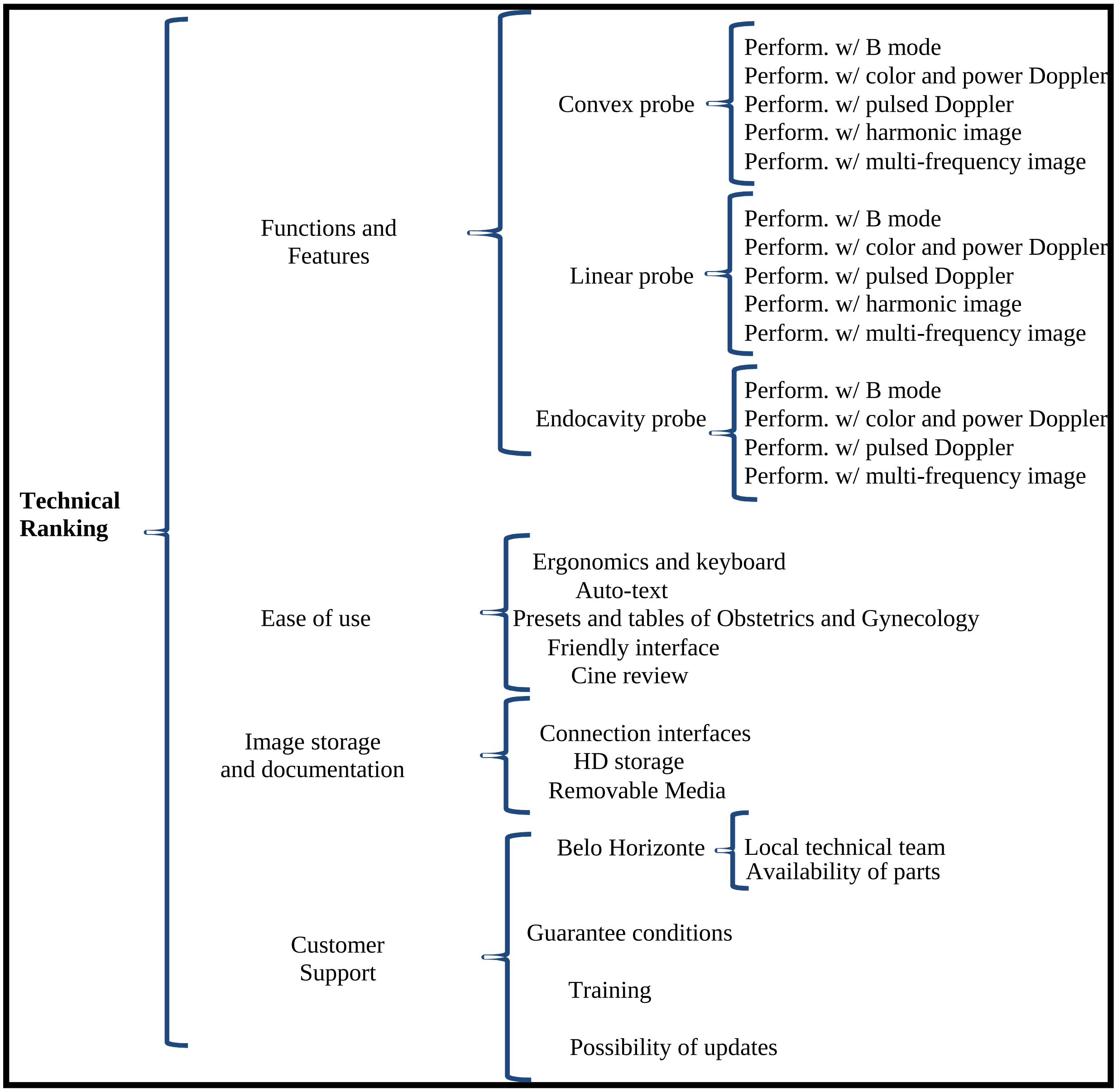

Figure 1. Proposed Decision Hierarchy for the Acquisition of Ultrasound Equipment.

In relation to the criterion "ease in use", the most valued subcriterion was the "ergonomics and keyboard" with 0.385, reflecting the physician's preoccupation with the command arrangement of the console and its positioning ease, adapting itself to the height of the different physicians that will utilize the equipment during the long work day. The second most valued subcriterion was the "friendly interface" with 0.246, referring to the software's useability. The third subcriterion was the "cine review" with 0.156, as a resource utilized principally for the choice of the best image for documentation. The other subcriteria such as auto-text, a resource that increases the productivity through the filling-out of pre-selected texts, and "presets and tables of gynecology and obstetrics", defined by the existence of pre-configurations and calculations available for various types of exams were, in this order, less valued.

Technical ranking 1 GOAL	Functions and features 0.568	Convex Probe 0.648	Perform. w/ B mode	0.495
			Perform. w/ color and power Doppler	0.14
			Perform. w/ pulsed Doppler	0.054
			Perform. w/ harmonic imaging	0.109
			Perform. w/ multi-frequency image	0.201
		Linear Probe 0.23	Perform. w/ B mode	0.354
			Perform. w/ color and power Doppler	0.101
			Perform. w/ pulsed Doppler	0.052
			Perform. w/ harmonic imaging	0.167
			Perform. w/ multi-frequency image	0.327
		Endocavity probe 0.122	Perform. w/ B mode	0.527
			Perform. w/ color and power Doppler	0.125
			Perform. w/ pulsed Doppler	0.061
			Perform. w/ harmonic imaging	0.287
	Ease of use 0.244	Ergonomics and keyboard	0.385	
		Auto-text	0.12	
		Presets and tables of OB/GYN	0.092	
		Friendly interface	0.246	
		Cine review	0.156	
	Image storage and documentation 0.112	Connection interfaces	0.4	
		HD Storage	0.2	
		Removable media	0.4	
	Customer support 0.075	Belo Horizonte 0.575	Local technical team	0.5
			Availabilities of parts	0.5
		Guarantee conditions 0.195		
		Training 0.127		
		Possibility of updates 0.103		

Figure 2. Subcriteria's local weight in relation to its node.

For the first level group "image storage and documentation", the most valued subcriterion was the "removable media" with 0.400, representing the means of recording for definitive archiving of the exams, along with the "connection interfaces" with 0.400, specifying the modalities available for image printing, demonstration or recording. The least valued subcriterion was the "storage on Hard Disk", keeping in mind that the equipment seen in the initial market research possessed at least 40 GB on the disk, more than sufficient for the daily storage of images at the Luxemburgo Hospital and even for passing to a definitive archiving in the removable hardware (DVD or recordable CD).

	Functions and Features	Ease in use	Image storage and documentation	Customer support	Weights calculated by the eigenvector
Functions and Features	1	3	5	6	0.568
Ease in use	1/3	1	3	3	0.244
Image storage and documentation	1/5	1/3	1	2	0.112
Customer support	1/6	1/3	1/2	1	0.075

Inconsistency: 0.03

Figure 3. Main criteria weights.

The criterion “customer support” had the subcriterion “in Belo Horizonte” with 0.575, as the most important, reflecting the value of proximity for technical care in the same city as the hospital for rapid problem solutions. The subcriteria “conditions of guarantee” and “training” were in second and third places in importance with 0.195 and 0.127 of the weight, respectively. The least valued subcriterion in the group was “possibility of upgrade” with 0.103, keeping in mind that, maintaining the Ultrasonic Hospital Service’s same level of demand, it wouldn’t be necessary to add additional resources.

In relation to the support criterion “in Belo Horizonte”, there was a tie at 0.500, between the subcriterion “local technical team” and “availability of parts.” The sucbcriterion “local technical team” reflects the given importance to the structure and qualification of the maintenance personnel, in hopes of less time stopped for a more efficient first line maintenance. The subcriterion “availability of parts” was considered due to the inventory of plates and probes in Brazil and in Belo Horizonte, as well as the client-aid policy in case of problems, keeping in mind that the Institution is philanthropic and subject to a larger delay in the importation of parts due to the governmental bureaucracy.

4.3 – Equipment offered by the competition: the alternatives

In response to the purchase requisition order sent to the four selected businesses to participate in the competition, the following equipment was offered, in the same price line and intermediate market share:

1. Siemens: model G40;
2. Toshiba: model Nemio SSA-550 A;
3. GE: model Logic 5 Pro;
4. Philips: model EnVisor SC.

The definition of the best equipment, outlined in quantitative measures, is not the objective of this study. Thus, we will substitute the brands and models offered in the competition with the letters "A" to "D" in relation to the sequence above.

The study's purpose is to obtain a technical ranking of the evaluated ultrasonic equipment based on a realistic point of view and the necessities of the Luxemburgo Hospital through qualitative criteria connected to the professional experience of the medical service representatives, being unnecessary to decline a result in itself, but having capital importance to the process's description of the evaluation technique and the definition of the criteria used for the Luxemburgo Hospital.

4.4 – Alternative Judgments by the Specialists

Once the proposals of the selected commercial equipment were received, the decision-making team evaluated each of the presented models within previously defined criteria, either as used in another hospital or ultrasonic service, or for a demonstration period in the institution.

After the evaluations, the decision-makers made and expressed their judgments in consensus, putting the data directly into the software Expert Choice. The alternatives were judged by pairwise comparisons for each criterion, using a fundamental scale with values from 1 to 9, as described in Saaty (2004), guaranteeing that the level of inconsistency remained within the permitted range.

4.5 – Time consumed in the process

As the decision-makers possessed more than one workplace, the quantity of hours used and the necessity of conciliating schedules for meetings were critical points for the decision-making process. The process consumed about 7 hours of each of the two decision-makers' time in the following ways:

1. 1-hour initial meeting in which the facilitator explained separately to each of the decision-makers, due to scheduling conflicts, the proposed methodology;
2. 1.5-hour meeting, held separately with each of the decision-makers, due to scheduling conflicts, in which the facilitator presented the criteria raised in the literature, an initial decision tree;
3. 2.5-hour meeting held with both decision-makers in which they arrived at a consensus about the decision tree, which served in the logbook for the equipment evaluation and for elaboration of the purchase requisition order;
4. 2-hour final meeting held with both decision-makers, in which the physicians, after having evaluated the equipment, offered their judgment in the form of a consensus on the software, and realized the sensitivity analysis.

During the time consumed in the process, the doctors involved became familiar with the equipment and how to operate it. In Brazil the doctors themselves do this kind of exam rather than a technician trained in the use of the ultrasonic device, such as in the United States. The process was conducted by an expert in the use of AHP theory.

5 – Results analysis

After the mathematical synthesis, the priority vectors for each alternative were obtained for each criterion. The global synthesis presented a ranking of the alternatives according to the priorities vector in relation to the goal, as demonstrated in Figure 4:

a. First choice: device D;
b. Second choice: device C;
c. Third choice: device A;
d. Fourth choice: device B.

This result can be seen in the first line of Figure 4. The other lines show how the eigenvectors calculated the normalization of the best device under each subcriteria having number 1.

	Alternatives	**device A**	**device B**	**device C**	**device D**
	Total	0.222	0.217	0.238	0.323
Functions and Features / convex probe /	Perform. w/ B mode (G: .182)	0.239	0.26	0.437	1
Functions and Features / convex probe /	Perform. w/ color and power Doppler (G: .051)	0.5	0.5	1	1
Functions and Features / convex probe /	Perform. w/ pulsed Doppler (G: .020)	0.5	0.5	1	1
Functions and Features / convex probe /	Perform. w/ harmonic image (G: .040)	0.367	0.367	0.817	1
Functions and Features / convex probe /	Perform. w/ multi-frequency image (G: .074)	1	1	1	1
Functions and Features / linear probe /	Perform. w/ B mode (G: .046)	1	1	1	1
Functions and Features / linear probe /	Perform. w/ color and power Doppler (G: .013)	0.413	0.413	0.704	1
Functions and Features / linear probe /	Perform. w/ pulsed Doppler (G: .007)	1	1	1	1
Functions and Features / linear probe /	Perform. w/ harmonic image (G: .022)	1	1	1	1
Functions and Features / linear probe /	Perform. w/ multi-frequency image (G: .043)	0.5	0.5	0.25	1
Functions and Features / Endocavity Probe /	Perform. w/ B mode (G: .037)	1	1	1	1
Functions and Features / Endocavity Probe /	Perform. w/ color and power Doppler (G: .009)	1	1	1	1
Functions and Features / Endocavity Probe /	Perform. w/ pulsed Doppler (G: .004)	1	1	1	1
Functions and Features / Endocavity Probe /	Perform. w/ multi-frequency image (G: .020)	1	0.5	0.5	0.5
Ease of use /	ergonomics and keyboard (G: .094)	1	1	1	1
Ease of use /	auto-text (G: .029)	1	1	1	1
Ease of use /	presets and tables OB/GYN (G: .023)	1	1	1	1
Ease of use /	friendly interface (G: .060)	1	1	1	0.5
Ease of use /	cine review (G: .038)	1	0.5	0.5	0.5
Image storage and documentation /	Connection interfaces (G: .045)	1	1	1	1
Image storage and documentation /	HD storage (G: .022)	1	1	0.539	0.311
Image storage and documentation /	removable device (G: .045)	0.5	0.5	0.5	1
Customer support / in Belo Horizonte /	local technical team (G: .022)	0.309	0.577	0.309	1
Customer support / in Belo Horizonte /	availability of parts (G: .022)	0.456	0.647	0.288	1

Figure 4. Results of the pairwise comparison.

Figure 5 shows the result of this valuation in the Expert Choice screen. The consistency of the decision-makers' judgments is evident in that the suggested maximum limit of the degree of inconsistency in each criterion and subcriterion was not surpassed in any case.

In simulation by the decision-making team, the sensitivity analysis showed itself to be useful in the following phase of the acquisition process: the commercial closing. Thus, in the case that the best commercial condition isn't relative to the first technical choice, and the institution opts for the second technical purchase option, the sensitivity analysis will permit the purchasing department to verify which criteria that provider will need to reinforce in its equipment in order to arrive at the closest possible priority vector obtained through the first technical choice. This improves the initial configuration of the offered equipment.

Such an analysis was facilitated by the program's functionalities for mathematical treatment, Expert Choice version 11, as it carries out an automatic recalculation and graphic redesign if the decision-makers alter the weight of a criterion. Thus, the impact this alteration would bring to the final ranking can be verified.

The final results analysis is thus aligned with the decision-making team's sentiment, expressing the preferences and expectations of the decision-makers in numbers.

The result can be expressed and decomposed for each criterion and subcriterion, permitting the data to be audited at any time.

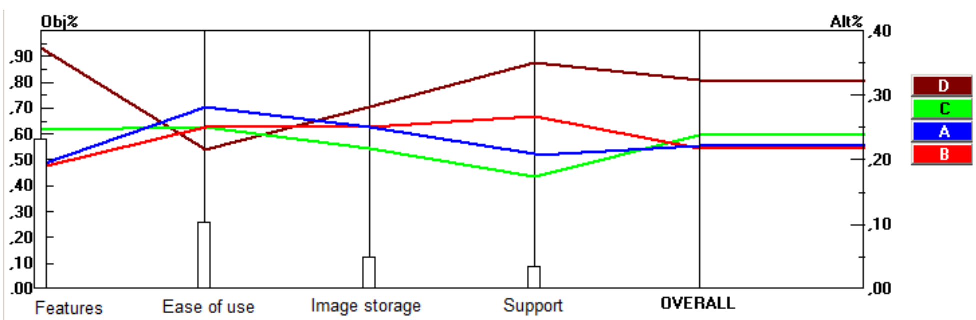

Figure 5. Results in the Expert Choice screen.

6 – Conclusions

The application of AHP achieved success in the proposed technical evaluation process's systemization and in the generation of a hierarchical tree model with criteria suggestion for technical evaluation of general use ultrasonic diagnostic equipment acquisition. The adhesion and understanding of the method by the medical decision-makers and the analysts were very much facilitated by the utilization of the program Expert Choice, which possesses an easy and intuitive utilization and interface. The medical decision-makers, despite their inexperience with the instrument, were able to manipulate the program, using their judgments and implementing alterations to the weights in the sensitivity analysis functionality.

As four alternatives were selected (equipment from different manufacturers) to participate in the purchasing process, the number of pairwise comparisons necessary for the evaluation of each final criterion was 6. As such, a total of 162 pairwise comparisons were necessary (6 x 27), once the 27 technical direct comparison criteria were defined with the construction of the hierarchical tree by the decision-makers.

Although the number of comparisons seems large, the values were inserted in the program Expert Choice at the same time that the decision-makers arrived at a consensus about the judgment. That process, along with the general checking of the judgments, took just two hours, and was not expressed as wearisome or tiring by the decision-makers. AHP showed itself to be a useful tool in the medical equipment acquisition process evaluation technique utilized due to:

a. The decomposition of the problem's complexity in a hierarchical tree that permitted the criteria's previous, clear definition to be evaluated and was fundamental as a guide for the elaboration of the competition purchase requisition order, as well as the logbook for the evaluation visits in the purchase process of the participating equipment installed in other hospitals.

b. The judgment of the weights and the notes provided an auditable map of the criteria and values used by the decision-making team, which can avoid possible indirect gains of members. The generated documentation functions as an auditable trail that permits the criteria, the criteria's weight and the judgment's values to be checked for each alternative ahead of the criterion by the director or an independent auditor. This grants transparency to the equipment's technical evaluation process.

c. The result can be expressed in a clear, systemized and numerical form, despite having been an extremely complex evaluation due to the number of variables and the equipment's technical attributes. Thus, a technical ranking of the evaluated alternatives that was generated can be compared with the ranking generated by the commercial evaluation, and carried out in a parallel process. That clear and defined criteria comparison permits the final decision about equipment purchase to be taken by the principal decision-maker of the institution (director), even if he or she is not from the medical sector, the technical sector (clinical engineering) or from the commercial area.

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