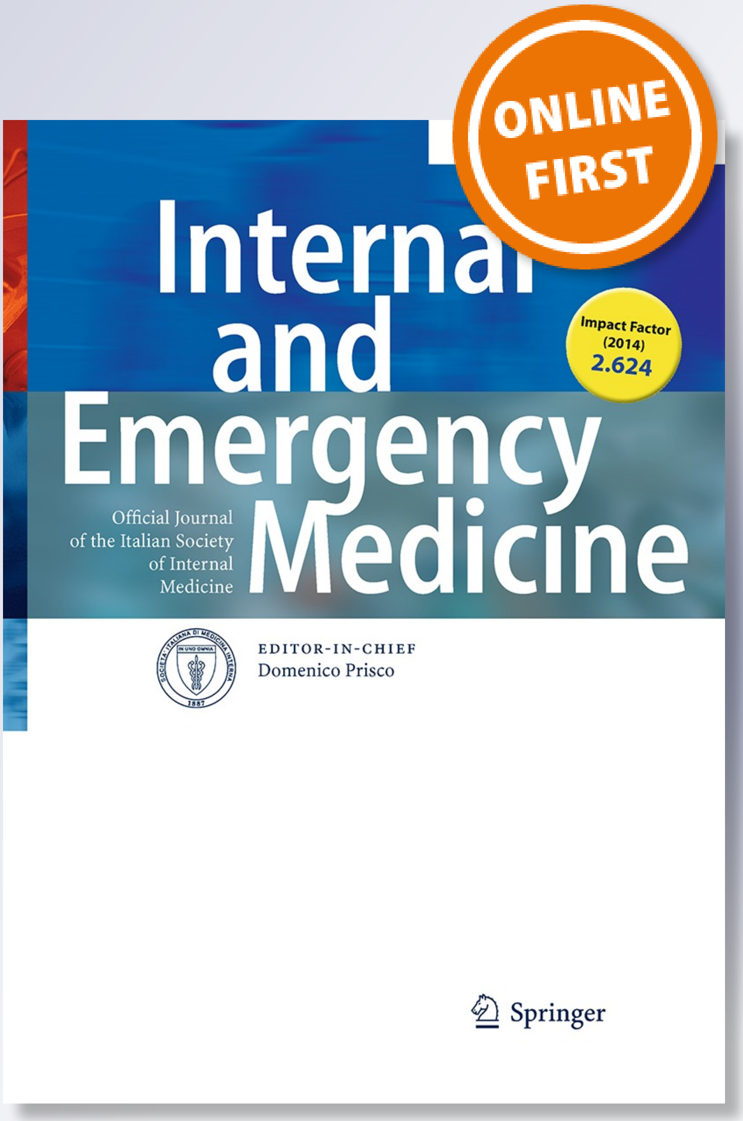
# *Economic analysis of bedside ultrasonography (US) implementation in an Internal Medicine department*

**Americo Testa, Andrea Francesconi, Rosangela Giannuzzi, Silvia Berardi & Paolo Sbraccia**

**Internal and Emergency Medicine**
Official Journal of the Italian Society of Internal Medicine

ISSN 1828-0447

Intern Emerg Med
DOI 10.1007/s11739-015-1320-7




Springer

Intern Emerg Med
DOI 10.1007/s11739-015-1320-7

CrossMark

HTA-ORIGINAL

# Economic analysis of bedside ultrasonography (US) implementation in an Internal Medicine department

Americo Testa[1,8] · Andrea Francesconi[2,3] · Rosangela Giannuzzi[4] · Silvia Berardi[5] · Paolo Sbraccia[6,7]

Received: 22 May 2015 / Accepted: 8 September 2015


**Abstract** The economic crisis, the growing healthcare demand, and Defensive Medicine wastefulness, strongly recommend the restructuring of the entire medical network. New health technology, such as bedside ultrasonography, might successfully integrate the clinical approach optimizing the use of limited resources, especially in a person-oriented vision of medicine. Bedside ultrasonography is a safe and reliable technique, with worldwide expanding employment in various clinical settings, being considered as "the stethoscope of the 21st century". However, at present, bedside ultrasonography lacks economic analysis. We performed a Cost–Benefit Analysis "ex ante", with a break-even point computing, of bedside ultrasonography implementation in an Internal Medicine department in the mid-term. Number and kind estimation of bedside ultrasonographic studies were obtained by a retrospective study, whose data results were applied to the next 3-year period (foresight study). All 1980 foreseen bedside examinations, with prevailing multiorgan ultrasonographic studies, were considered to calculate direct and indirect costs, while specific and generic revenues were considered only after the first semester. Physician professional training, equipment purchase and working time represented the main fixed and variable cost items. DRG increase/appropriateness, hospitalization stay shortening and reduction of traditional ultrasonography examination requests mainly impacted on calculated revenues. The break-even point, i.e. the volume of activity at which revenues exactly equal total incurred costs, was calculated to be 734 US examinations, corresponding to € 81,998 and the time considered necessary to reach it resulting 406 days. Our economic analysis clearly shows that bedside ultrasonography implementation in clinical daily management of an Internal Medicine department can produce consistent savings, or economic profit according to managerial choices (i.e., considering public or private targets), other than evident medical benefits.

**Keywords** Bedside ultrasonography · Echoscopy · Point of care ultrasonography · Internal Medicine · Costs benefit analysis · Economic analysis

**Abbreviations**

| | |
|---|---|
| ACEP | American College of Emergency Physicians |
| AIOP | Italian Private Healthcare Association |
| CBA | Cost-Benefit Analysis |
| BEA | Break-Even Analysis |
| BEP | Break-Even Point |
| CCNL | National Collective Labour Agreement |
| CT | Computed Tomography |
| CVP | Cost–Volume–Profit (analysis) |
| ED | Emergency Department |
| DRG | Diagnosis-Related Groups |

✉ Americo Testa
americotesta@gmail.com

1 Internal Medicine Unit, "Madonna delle Grazie" Clinic, viale S. D'Acquisto 67, 00040 Velletri (Rome), Italy

2 Department of Economics and Management, University of Trento, via Calepina, 14, 38122 Trento, Italy

3 Public Policy and Management Department, SDA Bocconi University, via Roberto Sarfatti 25, 20100 Milan, Italy

4 Emergency Medicine Department, "A. Gemelli" University Hospital, l.go A. Gemelli 8, 00168 Rome, Italy

5 Internal Medicine Unit, "A. Fiorini" Hospital, via Firenze 1, 04019 Terracina (LT), Italy

6 Department of Systems Medicine, University of Rome "Tor Vergata", Via Montpellier 1, 00133 Rome, Italy

7 Internal Medicine Unit, University Hospital Policlinico Tor Vergata, Viale Oxford 81, 00133 Rome, Italy

8 Via dei Laghi, 32, 00040 Rocca di Papa, Rome, Italy

Published online: 08 October 2015

| | |
|---|---|
| HTA | Health Technology Assessment |
| ICU | Intensive Care Unit |
| IM | Internal Medicine |
| NHS | National Healthcare Service |
| SAEM | Society for Academic Emergency Medicine |
| SIMEU | Italian Emergency Medicine Society |
| SIMI | Italian Internal Medicine Society |
| US | Ultrasonography |

## Introduction

A new organization of the entire medical network is recommended, taking into account cost restraints due to the worldwide economic crisis and growing healthcare demand for increasing actual and supposed needs, in the concept of an economically sustainable National Healthcare System (NHS). The Italian 2013 NHS expenditures accounted for 7.2 % of the country's gross domestic product, corresponding to € 106.7 billions, relatively lower than all European countries, accounting for 9–10 % of their countries' gross domestic product. Moreover, in Italy, it is substantially still for 6 years, and the new Health Pact 2014–2016 fixes to € 109.9 billions the Healthcare Fund for 2014, with increase to € 112.1 billions for 2015 and € 115.5 billions for 2016. This Health Pact is based on the rationalization of public expense (spending review), in particular regarding hospital assistance, either in terms of quality/quantity ratio or in terms of percentage of hospitalization [1].

In healthcare, environment technologic innovation is traditionally associated with the perception of an increase in costs, especially in the short term. The Health Technology Assessment (HTA) is a healthy political tool, internationally being used from the 90's, with the aim of supporting the decisional process by a multidisciplinary approach. HTA connects the world of research and the world of decision-making. It uses the best evidence available to value the economic (costs and benefits), medical (efficacy and safety), ethical, social, organizing, managerial and legal implications deriving from the introduction of a new technology in the system [2]. The introduction of an institutional model of HTA in matter of medical devices is encouraged by the new Italian Health Pact, according to the directive 2011/24/UE of the European Parliament.

Therefore, optimizing the use of limited resources is fundamental to limit inappropriate tests imposed by Defensive Medicine [3]. The role of old best clinical practice, such as history and physical examination, persists in being advocated. On the other hand, the gradual aging of the general population with increasing comorbidities, chronicity and frailty restores a central role to the internist as an expert of "medicine of complexity", reversing the trend from a disease-oriented to a person-oriented vision of medicine, by an integrated multidisciplinary holistic approach [4]. That is why the sick person should be perceived as a whole and not as the sum of his parts. New heath technology, such as bedside ultrasonography (US), might successfully integrate the clinical approach [5].

Bedside US is a safe technique, available even in poor environments, precise in a wide range of pathologic scenarios, legally performable by all physicians within their own specializations, and enforceable with clear objective in various clinical settings, being considered as "the stethoscope of the 21st century" [6–8]. Bedside US is now inserted among the compulsory professionalizing activities of different Specialization Schools, such as Internal Medicine and Emergency Medicine. Moreover, several Scientific Societies worldwide propose training in bedside US, either in emergency (ACEP, SIMEU) and more recently in IM settings (SIMI) [9].

At the root of the issue, there is the hypothesis that the routine employment of bedside US in an IM department provides a better efficacy (diagnostic–therapeutic aimed path, safety in procedures), and a greater efficiency (hospitalization stay shortening, fewer requests for imaging tests). Moreover, it represents an opportunity of professional growth for the physician. However, at present, we have not found specific economic analysis published on this argument. Primary objective of our study is the evaluation of the economic impact by cost–benefit analysis (CBA) of bedside US implementation in an IM department in the mid-term.

## Methods

### Study design

The project of "ex novo" bedside US implementation in an IM department was designed centering standardized criteria and local needs as specified in the following sections, and according to HTA approach. The CBA seemed appropriate in the development of the economic evaluation of the project. It allows a complete examination of relevant economic costs and benefits, in terms of individuation, measurement and monetization managed according to precise concepts of microeconomy. CBA is destined to compare the efficiency of an alternative (project of bedside US implementation) in a precise context (IM department) to reach a well-defined objective (saving or profit for the hospital) in comparison to the beginning ("status quo"). Traditionally the CBA develops "ex ante", and verifies whether benefits that the project can provide are more than related costs. From this, the project is judged useful or not.

This concept fits well to the current context of limited resources, by sustaining the decision-making (business, politics, etc.) of making choices that maximize the efficiency of its intervention [10].

An estimation of the operative risk in the mid-term has been made through the Break-Even Analysis (BEA), also called the Cost–Volume–Profit (CVP) analysis. This compares the relationship between the entity of the produced assets and the costs employed and the proceeds achieved by the firm. BEA is a managerial tool easily applicable to mono-product firms. The break-even point (BEP) in particular provides the performance measure, expressed in volume of activity (examination number) or the global amount of sales (€ = euro) required for exactly covering the total incurred cost, with the aim of catching a balanced budget, i.e., revenues = variable costs + fixed costs. Similar to this, the break-even period is the corresponding time, necessary to reach the volume or the proceeds of sales cited by BEP [11].

## Actors and receivers

As reference center of our study, we choose the IM department of "Madonna delle Grazie" Clinic in Velletri (Rome). It includes 33 beds for acute patients credited to NHS, with mean time of hospitalization of 10.0 days and beds occupation rate of 0.87. In the first semester 2014, 515 patients were hospitalized, their mean age being 73.3 years, with F/M ratio = 1.08; 2/3 of them came from home and 1/3 from the ED of the city hospital. The Clinic does not have an ICU; so the patient selection excluded from the beginning critical and traumatized patients. The IM department staff includes four physicians (a director and three physicians).

The Clinic was identified as the reference group for policy making. It is the first receiver of all the interventions whose economic costs and benefits were calculated. IM department was the principle receiver of organizing and management relapses of the project itself. The impact that this project could have on each patient, direct receiver of clinical efforts, and on social and institutional settings was not analyzed.

## Time and procedures

We designed our project in a mid-term (3 years). It seemed adequate to let a proper time for amortization of the initial economic investment destined to staff training and to machine purchase, and warrant an adequate training and get over the organizing and managerial problems. The economic analysis of the project included 3 distinct phases: (a) Identification, measure and exploitation (monetization) of sustained costs for the new technology introduction; (b) identification, measure and exploitation (monetization) of benefits (revenues) provided by the new technology compared to the previous situation; (c) comparison of costs and benefits.

Costs were classified as direct and indirect. They represent the value of material and human resources involved during the start of the project and spent in its realization. Direct costs, further parted in fixed and variable, have included the costs of training, of equipment purchase and its maintenance, of the initial increase of examinations requests, of consumables, and of medical and hospital services. The unsanitary costs, difficult to value, were not included in the project. Similarly, indirect costs linked to the realization of the project including the general functions as administration and book-keeping, direction, assistant services, electricity, management of the store and cleaning were overlooked.

Revenues are parted in specific, directly consequent to the performance of US examination (DRG increase/appropriateness, hospitalization stay shortening, procedures safety, clinical efficiency, mistakes reduction), and generic, indirectly derived from it (saving travel time, less request of imaging tests). In order to calculate revenues not only on theoretical values, the actual impact of bedside US employment in the same department in the first semester 2014 has been evaluated. In fact, our IM department belongs to the national network of the SIMI school in "Bedside US" [9], and during the study period continuously hosted several students attending the practical stage of the school, under the supervision of teachers (the head physician of the ward and other teachers belonging to other departments or hospitals). Unfortunately, no previous period without bedside US application was available in our IM department, useful to perform a comparative analysis of the work before and after "ex novo" implementation of bedside US. Moreover, bedside US didactic activity performed during the first semester 2014 did not cover all the requests of the ward. On the other hand, a complete estimation of the number and kind of bedside US foreseen in 3-year period was considered to be necessary for correctly performing CBA. So, this evaluation was obtained retrospectively analyzing each case sheet of patients admitted in the ward during the first semester 2014, in order to predict all feasible bedside US fitting a full adoption of new technology.

Bedside US examinations were performed upon admission to the ward, during hospitalization and after the discharge (follow-up). On the basis of performed bedside US and according to literature reports, the variety of bedside US was codified into five types [5–7, 9, 12, 13]: (1) *Multiorgan US* dyspnoea, hypotension/shock, chest pain, syncope, fever/sepsis, abdominal pain, urinary tract disease/renal failure; (2) *Focused US* swelling limb, soft tissue swelling, peripheral chest pain, thyroid disease; (3) *Follow-*

*up US* only composed by lung US; the examination was not performed by local Diagnostic Imaging Service; (4) *Interventional US* only thoracentesis and paracentesis were included; US employment in venous line achievement, though widely validated in literature, found in our experience only occasional use; (5) *Critical US* emergent application of bedside US, it consists of an integrated US approach into the algorithm for cardiac arrest and periarrest condition, to recognize reversible causes even improving patients outcome.

The entity of each input or output variables has been measured, before as unitary and then as general, referred to the first semester 2014 (retrospective case study). The value has been then developed by considering all estimated feasible bedside US in the same period. Finally, the data results obtained by the retrospective study were applied during the next 3-year period (foresight study). We assign a value to each variable, according to real prices or according to business: in particular, detailed costs concerning US equipment, US gel, thermal print media and soft paper roll were collected by commercial proposal without specific negotiation. In the end, prices were multiplied by the estimated amount to reach aggregate values. To calculate costs, all bedside US examinations estimated in 3 years were considered. In proceeds analysis, the first semester of the foresight study was excluded from the count, taking into account an unproductive early phase due to the learning curve. To estimate the value of not available data in retrospective study, above all due to the poor number of US examinations performed (i.e., interventional and critical US), we referred to data from the literature.

## Results

### Bedside US analysis

*Retrospective study (I semester 2014)* 232 bedside US examinations were performed in 515 patients, with a multiorgan US ($N = 183$) prevalence. Of them, 104 were positive (pathologic) and 128 negative (not pathologic) (Table 1). Moreover, 86 unexpected results (not searched for disease) or unknown (otherwise not documented) were found.

60 out of 104 bedside US with positive results had a measurable role in proceeds, in terms of shortening of hospitalization and reduction of traditional US examination requests. Of the remaining 44 bedside US: 31 multiorgan US were excluded from the count of revenues, as the findings have been confirmed by other imaging studies, four interventional and one critical US were considered for increase in safety/efficacy as far as proceeds, and eight follow-up US were included among general revenues as sparing radiographies not requested. 128 bedside US with negative results were excluded from revenues count as considered irrelevant. 86 unexpected or unknown results were distributed as follow: 38 lung diseases (of which 22 pleural effusions), 15 cardiac diseases (10 pericardial effusion), 14 abdominal diseases (five cancers), 11 renal diseases (four urinary bladder overdistensions), eight other findings (two necrotizing fasciitis). Among 38 lung diseases unexpected or unknown, 16 contributed effectively to an increase of final DRG, providing an accurate depiction of the disease (i.e., pneumonia not found in chest X-ray) or showing a complication not otherwise found (i.e., pleural or pericardial effusion). In 21/86 cases bedside US results influenced clinical management in some fashion, but it was not possible to evaluate its real economic impact. Finally, in remaining 49/86 cases of unexpected or unknown bedside US results seemed irrelevant as far as proceeds count. In fact, most of them were included in final diagnosis without contributing to increase DRG (i.e., pleural, pericardial or abdominal effusion in heart failure, bilateral pleural effusion or multiple lung consolidation, or interstitial pattern in pneumonia, liver metastases). Remaining abnormalities were considered without clinical relevance (inflammatory lymph nodes, soft tissue swellings, renal cysts), rarely investigated by specialist consulting or biochemical markers (thyroid nodules, uterus abnormalities, ovarian cysts), more frequently embedded into further investigation during outpatient clinic management or long-term follow-up (gallbladder and kidney stones, small aortic aneurysm).

In the first semester 2014, the overall estimation of feasible bedside US was 330 (compared to 232 really performed: increasing factor = 1.42).

*Foresight study* Developing the results of the retrospective study, the following data per semester resulted over the mid-term simulation: 148 positive results, 86 of which involved hospital course in terms of reduced hospitalization and reduction of US examination requests, 44 multiorgan US excluded, seven interventional and critical US included in proceeds as increased safety/efficacy, and 11 follow-up US, calculated in proceeds because it spared chest X-ray studies. 182 negative bedside US were considered irrelevant. Finally, 122 unexpected and unknown bedside US results, 23 of which were considered as of actual influence in terms of DRG increase/appropriateness.

To calculate costs, all 1980 foreseen bedside US examinations were considered (330/semester multiplied for 6). Revenues have been estimated only after the first semester from the beginning of the project, due to completion of learning curve, so considering a total of 1650 examinations (1980-330). No other further increase of managerial and organizing activities, nor logistic challenges of dividing spaces and times resulted in our analysis.

**Table 1** Variety and results of the bedside US performed in the first 6-month period of 2014 in the IM Department

| Bedside US variety | Total number | Positive results | Negative results |
|---|---|---|---|
| Multiorgan US | 183 | 82 | 101 |
| Dyspnoea | 48 | 31 | 17 |
| Hypotension/shock | 38 | 19 | 19 |
| Chest pain | 3 | 0 | 3 |
| Syncope | 2 | 0 | 2 |
| Fever/sepsis | 13 | 2 | 11 |
| Urinary tract disease/renal failure | 15 | 8 | 7 |
| Abdominal pain | 64 | 22 | 42 |
| Focused US | 35 | 9 | 26 |
| Swelling limb | 10 | 2 | 8 |
| Soft tissue swelling | 9 | 4 | 5 |
| Peripheral chest pain | 1 | 1 | 0 |
| Thyroid disease | 15 | 2 | 13 |
| Follow-up US (lung) | 8 | 8 | 0 |
| Interventional US | 4 | 4 | 0 |
| Thoracentesis | 2 | 2 | 0 |
| Paracentesis | 2 | 2 | 0 |
| Critical US | 2 | 1 | 1 |
| Total | 232 | 104 | 128 |

## Economic analysis

*Identification, measure and exploitation (monetization) of costs (Table 2)*

*Fixed costs* *Physician professional training* In the training program three physicians were included (two with helping contract and one as assistant). The amount of daily work was calculated on the basis of the wage per hour according to CCNL AIOP (€ 35.33/h and € 29/h, respectively). Training program included the SIMI certificate of competence of first level of bedside US [9], that is a theoretic bedside US course held every year in the SIMI National Congress (entrance fee € 200), a theory and practical two-day bedside US course organized by one of the SIMI national schools (entrance fee € 488), and a 1-week practical bedside US training stage in a US SIMI center willing to accept probationers (a flat rate of € 100/day was calculated). The advanced program training included the advanced theory and practical course by SIMEU (during the National Congress, € 700), and the second level of practical bedside US two-week training stage in a SIMI center (flat rate of € 100/day). To all physicians involved in the training the book "Ecografia Clinica in Urgenza-Emergenza" (Scuderi M., Minerva Medica, Turin, 2008: € 124) was provided.

*Journey fee* All courses and stages were considered according to residence region (though not necessary). It was calculated a contract price for transfer of €100 per person. All inclusive costs for stay have been calculated in € 150/day per person.

*Equipment purchase* Based on a training offer, the expense for a portable US machine (Samsung MySono U6), equipped with 3 probes (phased array, convex and linear) and a print (Sony HPP-110HG) was calculated in € 34,770 (VAT included). Equipment service secured for 3 years (Platinum Extension Warranty) was € 8.052 (VAT included).

*Initial increase of "traditional" US examinations requests* It has been foreseen an initial costs increase of traditional US examination requests (I semester of foresight study), due to better technique knowledge and the need of a "second opinion" [14]. According to literature, it was estimated an increase till 90 % of examinations that, developed in 6 months, arrived to 340 more US examinations ($0.9 \times 3$ examinations/day $\times$ 126 working days). During the second semester it was estimated a requests balance compared to the previous situation. Finally, after 1 year it was applied the count of the expected decrease, while physicians acquire an even greater expertise in bedside US.

*Variable costs* *US gel* It was estimated that a 260 ml bottle of gel (€ 0.6334) is sufficient to perform five US examinations: we make allowance of 80 % examinations included gel consuming multiorgan US.

*Thermal print media* We fixed maximum 4 printed images per US examination, resulting in 18 m roll (€ 12.81) each 45 examinations (measure images are 10 cm = 40 cm/examination: 1800/40 = 45 examinations/roll).

**Table 2** Costs elaboration

| Good type | Considered variable | Measure (impact) | Monetizing (aggregate values, euro) |
|---|---|---|---|
| Input | Direct costs | | |
| | Fixed costs | | 73,543 |
| | Training | | |
| | Theoretical basic course (congress) | 3 courses/3 ds/6 travels | 1650 |
| | Basic stage (1 week) | 3 stages/18 ds/6 travels | 5100 |
| | Basic theoretical-practical course | 3 courses/6 ds/6 travels | 2964 |
| | Advanced theoretical-practical course | 1 course/5 ds/2 travels | 1650 |
| | Advanced stage (2 week) | 1 stage/12 ds/2 travels | 3200 |
| | Books | 3 books | 372 |
| | Paid working days | 35ds + 9ds | 8985 |
| | Equipment | | |
| | US purchase | 1 US machine | 34,770 |
| | Upkeep | 3 years | 8052 |
| | Initial increase of traditional US (I semester) | 340 examinations | 6800 |
| | Variable costs | | 22,808 |
| | Consumables | | |
| | Gel (1/5 examinations) | 396 bottles | 252 |
| | Thermal print roll (1 roll/45 examinations) | 44 rolls | 564 |
| | Soft roll paper (800 blotting paper, 5/exam.) | 12 rolls | 67 |
| | Working hour (20 min/examination) | 660 h | 21,925 |
| | Overtime performances | 756 examinations | ± |
| | False + and − results and unexpected findings | ? | – |
| | Indirect costs | | |
| | Management, auxiliary service, cleaning, etc. | ? | – |
| Total | | | 96,351 |

*Soft paper roll* To clean patient and probe from gel we calculated necessary 5 blotting papers per each US examination (€ 5.45 each roll).

*Time per examination* We estimated 20 min per US examination, including reporting. The cost per hour of work calculated divided by three physicians is in mean € 33.22/h. The concept of cost-opportunity was evaluated in terms of worked hours.

*Inappropriate US machine employment* Extra-ordinary requests, beyond the ward necessity, may occur. It is also known that the availability of an US machine on the ward led to several requests by colleagues, friends, or out-of-hospital patients. It derives a lack of time and resources from the firm, though in part these activities are often performed overtime. Considering an arbitrary estimation of 1 US examination day, multiplied for 756 working days (count made over 3 years), there are a total of 756 examinations. We did not associate a cost with this because this gave us benefits in terms of good reputation, trust of patients, increase of productivity and sparing of working days for services for workers.

*False positive and negative results and unexpected findings* Costs linked to diagnostic errors were not calculated, though not negligible, especially in the first period of training. In the same way, marginal costs arising from adjunctive investigations in unexpected findings were not computed. However, these can be found as negative qualitative evaluation in Table 2.

*Indirect costs* associated to the project realization, though included in negative qualitative evaluation in Table II, have been excluded from the quantitative count as considered negligible.

*Identification, measure and exploitation (monetization) of revenues (Table 3)*

*Specific revenues DRG increase/appropriateness* The revenues produced by 23 unexpected or unknown results, all of them lung diseases, is € 35,069. This aspect is also confirmed by recent literature, in which lung US is more accurate than physical examination or chest X-ray, as much as to provide for a possible reduction of imaging as chest X-ray and CT [15].

*Hospitalization stay shortening* It was calculated on 86 patients per semester and estimated in 2 days per patient,

**Table 3** Revenues elaboration

| Good type | Considered variable | Measure (impact) | Monetizing (aggregate values, in euro) |
|---|---|---|---|
| Output | Specific revenues | | 324,471 |
| | New diagnosis | | |
| | DRG increase/appropriateness (>I semester) | 115 cases | 175,345 |
| | Prompt diagnosis | | |
| | Hospitalization time reduction (>I semester) | 860 days | 146,200 |
| | Interventional US safety (lesser complications) | 0.2/30 cases | 2926 |
| | Emergency management efficacy (arrest) | 1.7/15 cases | + |
| | Therapeutic efficacy | ? | + |
| | Diagnostic/therapeutic mistakes reduction | ? | + |
| | Generic revenues | | 10,617 |
| | Saving patient transfer (other US in wards) | 756 exam (189 h) | 2912 |
| | Saving imaging for follow-up (>I semester) | 55 examinations | 825 |
| | Saving traditional US (>I year) | 344 examinations | 6880 |
| | Less exposition to ionizing radiation | ? | + |
| | Patient trust in Hospital | ? | + |
| | Physician motivation | ? | + |
| Total | | | 335,088 |

corresponding to common waiting time for a traditional US examination in our ward. Overall hospitalization time reduction resulted of 860 days (86 × 2 × 5). The unit value attributed was calculated according to DRG mean value per day, estimated as € 170. This result has been inferred by the ratio between the total DRG count in euro and the related days of hospitalization cost (€ 278.9). To this value the percentage of bed occupation (0.87) was applied and deducted variable costs, estimated to 30 % of total.

*Interventional US safety* Literature provides data from the systematic use of US in procedures. Based on several data, it was calculated a 19 % reduction of pneumothorax during thoracentesis (complication prevalence = 0.8 %) [16]. According to this work, each avoided pneumothorax would have spared $ 2801 and 1.5 days of hospitalization, while for haemorrhagic complication would have been spent $ 19,066 and 4.3 days of hospitalization. In our foresight study, out of 15 thoracentesis should have been avoided 0.1 pneumothorax (15 × 0.027 × 0.19) and 0.1 bleeding (15 × 0.008 × 0.68), sparing $ 280 and $ 1907, respectively (for a total of € 2824) and 0.6 days of hospitalization (170 × 0.6 = € 102).

*Critical US efficacy* US employment in emergency (arrest/periarrest) is widening spreading rapidly in many contexts, especially in ED, in ICU and in many wards [13]. Our retrospective study provided poor data to make a real evaluation of critical US economic impact. Similarly, limited reports were available in literature. So, only a positive qualitative evaluation to critical US was attributed in our analysis. Although, in a recent study conducted on 88 patients suffering from cardiac arrest in a pre-hospital setting, caused by a not shockable rhythm, US has been feasible in 96 % of cases, and thus changing its management in 78 % of cases, deriving a survival rate of 40 % versus an expected survival rate of 3.85 % [17, 18]. Though considering the effective outcome (surviving to discharge) that could be estimated of 36.5 %, there is a mortality reduction of 1.7/15 patients. 15 arrests managed by US are poor and are underestimated, above all in a context where all physicians have US expertise.

*Therapeutic efficacy of bedside US* Estimated in terms of fewer expected complications, less hospitalization time and better quality of life, potentially derived by the more accurate and prompt therapeutic decisions taken after bedside US performance. Bedside US therapeutic efficacy was estimated impossible to evaluate in economic terms in our study.

*Reduction of diagnostic–therapeutic mistakes* Bedside US provides additional data since the beginning of diagnostic procedure. Even this has not been evaluated economically, but it received a positive qualitative evaluation.

*Generic revenues US machine use by other physicians* This occasion includes the performance of II level US examinations into the ward, and it has been projected over 3 years. It was calculated 1 US examination a day for a total of 756 working days, so 756 US examinations. Time spending in moving the patient was 15 min/patient and the cost for a person that moves him € 15.41/h.

*Chest X-ray sparing* The better accuracy of bedside US than chest X-ray in detecting the main lung disease and the consequent reduction of radiologic lung imaging are well documented in literature [15, 19]. In our study we assessed a possible saving of radiologic examinations among patients submitted to lung US follow-up, during hospitalization or after the discharge, generally for disease already detected by the same technique (pericardial and pleural effusions, interstitial pneumonia). We estimated 11 US examinations/semester, predicting 55 follow-ups. Radiologic examinations saving resulted in € 825 (55 examinations × € 15).

*Traditional US saving* This is referred only to the US examinations performed in our Diagnostic Imaging Service. So, the majority of multiorgan US and all lung US, follow-up US, interventional US and critical US were excluded. In the retrospective study, 60 traditional US were saved (86 estimated), with a sum of 344 examinations (86 × 4 semester), saving € 6800 (€ 20 each US).

*Radiation risk reduction* This aspect, ethical rather than economic, seemed limited in our study, and was estimated only as a qualitative positive evaluation.

*Trust of patients* The potential role of bedside US is clear, as it is a technologic tool binding physician to the patient and giving him satisfaction. Moreover, bedside US increases the relationship between patient and physician, and increases trust of the patient. Even to this point, it is possible only to attribute a qualitative positive value in our analysis.

*Sanitary motivation* Even this point, witnessed by the authors and a wide literature, is hard to explain by economic tools and has been evaluated as qualitative positive.

*Costs/revenues comparison (Fig. 1)*

Plotting our collected data in the BEA graph, where in the abscissa there is the activity volume (bedside US examinations performed), and in the ordinate the economic value of employed resources (fixed costs, variable and total costs) and of revenues, we can observe the productive course of the project, verify profit and loss account, and collocate BEP. In terms of "activity volume", BEP resulted of 734 performances, and in terms of "economic value" it was € 81,998. Finally, the time considered necessary to reach it (Break Even Period) was 406 days. Following derived quantities are also provided by BEA: fixed costs (€ 73,543), unit profit (€ 169, resulting 203 after first semester), unit variable cost (€ 11.5), unit contribution margin (€ 157.5, resulting 191.5 after I semester).

Costs and revenues course are usually linear and so represented as a line. In our study, the line of revenues is drawn by an initial plateau = 0, as in the first semester proceeds are 0. Moreover, there is thought to be a perfect

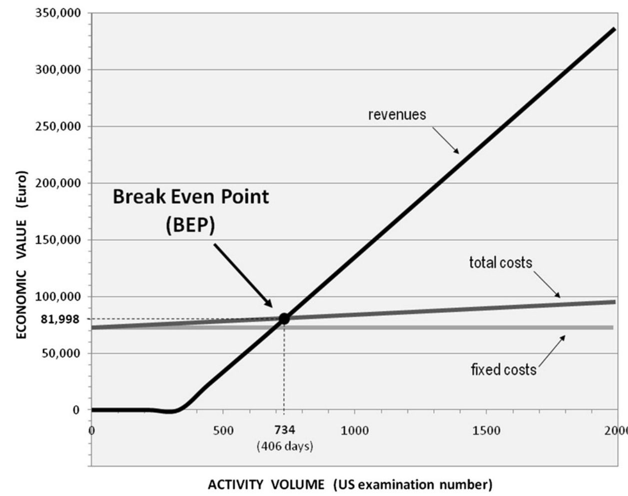



**Fig. 1** Cost–Volume–Profit (CVP) analysis outlines total benefits trend versus total costs (in euro) according to performances supplied (activity volume). In graph BEP is plotted, related to 734 bedside US examinations performed, or 406 days from the beginning of the project

division among fixed and variable costs, not always actually feasible.

## Discussion

Our economic analysis "ex ante", based on retrospective data results, clearly shows that the bedside US implementation in clinical daily management of an IM department can produce consistent *savings*, or *economic profit* according to managerial choices (i.e., considering public or private targets), other than evident medical benefits. Evidence is even stronger considering the minimal *organizational* and *managerial impact* due to the introduction of the new technique. Given a moderate economic initial investment and an initial phase of nonproduction due to the learning curve, in our project the firm would start to pull savings, or receive profits, soon after the first year of activity (406 days). The same results emerged in other sanitary contexts, though by qualitative evaluation rather than by detailed economic analysis. In the ED, bedside US provides a reduction of hospitalization period by reducing recurrence rate for the same pathology, and thus reducing patient management costs [20], also showing very low error rate and eliciting high patient satisfaction [21]. The use of compression US to identify deep vein thrombosis in hemodynamically stable patients with signs and symptoms suggestive of pulmonary embolism is proposed as a cost-effective alternative to CT imaging, also reducing ionizing radiation exposure and adverse events associated with CT contrast media [22]. In the meanwhile, bedside US performed by General Practitioners could be cost-effective by determining a decrease in imaging tests requests, a more appropriateness of their requests, a higher patient satisfaction and finally a reduction of direct and indirect costs, either for healthcare or for patient. However, so far it is not widely employed in outpatient medical bureau and in pre-hospital emergency medical services, so far the cost of equipment and training representing the most significant barriers to implementation of bedside US [23, 24]. Moreover, bedside US could contribute to limit inappropriate performances due to Defensive Medicine, argument of discussion of choosing wisely campaign by the American Board of Internal Medicine Foundation [3]. Within this context, our study demonstrates that in an IM department bedside US might improve management of urinary catheter, pneumonia, heart failure and duration of hospitalization. Assessment of *medical implications* due to the introduction of bedside US is complex as far as quantitative evaluation, and as much foregone as far as qualitative one. US may actually be useful in a nearly head-to-toe examination of the patient. Few organs seem to be off limits for modern US, including traditionally “overlooked” organs such as lung. So, bedside US provides a completely new approach for clinicians in patient management and care. The new paradigm of bedside US, believed to be a new kind of stethoscope, is that physician can use it to confirm or investigate the initial diagnostic impression arising from clinical assessment of the patient, and eventually perform also an US-guided interventional procedure [25].

In our economic analysis, the costs organization was able to include almost all the points, excluding only costs related to diagnostic mistakes and unexpected findings. These last, included in routine US examinations, are reported with low prevalence (7.6 %) in middle-aged medical outpatients, regarding long-term follow-up as necessary in 0.1 % and without eventual therapeutic implications in any patient [26]. Likely, focused bedside US should produce less unexpected findings than routine second level US, although these one are more prevalent in older hospitalized population.

Profit analysis instead was not able to monetize different aspects of specific and generic revenues. Among specific revenues, benefits derived from the care promptness and the higher carefulness should be emphasized, enabled by a more accurate diagnosis. Consequent benefits in terms of fewer complications and mistakes, fewer lawsuits, reduced hospitalization period and better patient quality of life, though difficult to evaluate in economic terms, surely compensate costs from eventual diagnostic mistakes and unexpected findings.

*Social* and *ethical implications* appeared clearly beneficial, and were expressed in our analysis as generic revenues. The opportunity of reducing the employment of imaging with ionizing radiation (traditional radiology, CT), is also not trivial. Which bedside US increased usage could contribute [19, 25]. Besides economic impact, this theme is very important on the social plane wherein tumor future incidence is judged not marginal due to the wholesale increase of CT examinations [27]. Due to the mechanic and thermic energy to tissues, US is recognized as a safe tool for the patient. This improves also the medical–patient relationship, so that patients, as they are satisfied by medical performances, are more precise in taking medications. The efficacy of care involves all sanitary context, public and private ones. From this, trust management is even more increasing during last years, as tool to boost patient trust through a better communication, better professional quality and the complete assurance of needs. Finally, among generic proceeds it should be considered that learning a new technology can increase culture and medical profession motivation. Its positive relevance is easily referable to a better productivity and a reduction of clinical risk by physicians: a motivated physician works better!

Economic analysis of our project presents several *limits* and approximations. Firstly, findings from our study cannot be generalized. In fact, external validity might be affected by a poorly representative sampling, above all due to patient selection and its impact on the prevalence and seriousness of disease. Moreover, the choice of the January–June semester can constitute a bias in selection of seasonal diseases. Likely, the results might be affected by different costs/prices, due to different negotiation power between private and public institutions, or between great and small entities. Secondly, some benefits deriving from the project (i.e., DRG increase) can be limited or eliminated in a context with a defined budget, above all in clinic operating within the NHS, not motivated to be more productive. On the contrary, for a private or public firm without a budget limit, anything that can improve system efficiency should represent an incentive. Thirdly, CBA used in our study, besides requesting a lot of information and the solution of some critical issues (i.e., impact of therapeutic efficacy, diagnostic mistakes, radiation exposure, staff motivation, etc.) is often the object of radical criticism. In particular, in cases in which intangible or barely monetizing goods are involved, we often do not assign an economic value. In economic studies that request accurate operative limits, a Sensitivity Analysis should be used, which is a test to evaluate the stability of study conclusions. In the same way, the Budget Impact Analysis was omitted. It should include the monitoring of costs and benefits for a long time (i.e., 10 or 25 years), because benefits due to the introduction of a new technology continue during time. Finally, we acknowledge that the complete application of our proposal has no chance in daily reality, and it constitutes the most important limit in our study. In fact, bedside US represents a radical cultural innovation, other than technologic. Of course, human psychological resistances continue to be the actual issue in promptly effecting a complete implementation of bedside US [28], more than the economic barriers [23, 24].

In conclusion, our study encourages the employment of bedside US in daily clinical practice of an IM department. Both the use of a medical tool (a portable US machine) and the performance of a new technology are involved, constituting a cultural challenge. It is easily predictable that a full application of bedside US would be reached slowly, by way of generational gap. Together with its growing voluntary adoption in various institutions and settings, it is desirable that its training enters into academic education courses, in order to bring the bedside US to universal fruition.

**Compliance with ethical standards**

**Conflict of interest** The authors have no potential conflict of interest.

**Statement of human and animal rights** All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the author.

**Informed consent** For this type of study formal consent is not required.

## References


1. Conferenza permanente per i rapporti tra lo Stato, le Regioni e le Provincie autonome di Trento e Bolzano. Nuovo Patto per la Salute per il 2014-2016. http://www.governo.it/GovernoInforma/Dossier/patto_salute/Conferenza_SR.pdf. Accessed 20 Jan 2015
2. Noorani HZ, Husereau DR, Boudreau R, Skidmore B (2007) Priority setting for health technology assessment: a systematic review of current practical approaches. Int J Technol Assess Health Care 23:310–315
3. Horwitz LI, Masica AL, Auerbach AD (2014) Introducing choosing wisely®: next steps in improving healthcare value. J Hosp Med Dec. doi:10.1002/jhm.2305 **[Epub ahead of print]**
4. Cervellin G, Borghi L, Lippi G (2014) Do clinicians decide relying primarily on Bayesians principles or on Gestalt perception? Some pearls and pitfalls of Gestalt perception in medicine. Intern Emerg Med 9:513–519
5. Arienti V, Camaggi V (2011) Clinical applications of bedside ultrasonography in internal and emergency medicine. Intern Emerg Med 6:195–201
6. Neri L, Storti E, Lichtenstein D (2007) Toward an ultrasound curriculum for critical care medicine. Crit Care Med 35(5):S290–S304
7. Moore CL, Copel JA (2011) Point-of-care ultrasonography. N Engl J Med 364:749–757
8. Gillman LM, Kirkpatrick AW (2012) Portable bedside ultrasound: the visual stethoscope of the 21st century. Scand J Trauma Resusc Emerg Med 20:18
9. Arienti V, Di Giulio R, Cogliati C, Accogli E, Aluigi L, Corazza GR, Ultrasound SIMI Study Group (2014) Bedside ultrasonography (US), echoscopy and US point of care as a new kind of stethoscope for internal medicine departments: the training program of the Italian internal medicine society (SIMI). Intern Emerg Med 9:805–814
10. Wang SJ, Middleton B, Prosser LA et al (2003) A cost-benefit analysis of electronic medical records in primary care. Am J Med 114:397–403
11. Khurshid R, Tabish SA, Hakim A, Khan A, Singh Y (2014) Break-even analysis of MRI facility at a large tertiary care teaching hospital of North India. I J M A H S 2:220–222
12. American College of Emergency Physicians (2008) ACEP policy statements. Emergency ultrasound guidelines, pp 1–38. http://www.acep.org
13. Testa A, Cibinel GA, Portale G et al (2010) The proposal of an integrated ultrasonographic approach into the ALS algorithm for cardiac arrest: the PEA protocol. Eur Rev Med Pharmacol Sci 14:77–88
14. Heller M, Melanson S, Patterson J, Raftis J (1999) Impact of emergency medicine resident training in ultrasonography on ultrasound utilization. Am J Emerg Med 17:21–22
15. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ (2004) Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology 100:9–15
16. Mercaldi CJ, Lanes SF (2013) Ultrasound guidance decreases complications and improves the cost of care among patients undergoing thoracentesis and paracentesis. Chest 143:532–538
17. Breitkreutz R, Price S, Steiger HV et al (2010) Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: a prospective trial. Resuscitation 81:1527–1533
18. McNally B, Robb R, Mehta M et al (2011) Out-of-hospital cardiac arrest surveillance—cardiac arrest registry to enhance survival (CARES), United States, October 1, 2005–December 31, 2010. MMWR Surveill Summ 60:1–19
19. Peris A, Tutino L, Zagli G et al (2010) The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computed tomography scans in critically ill patients. Anesth Analg 111:687–692
20. Vairo G, Salustri A, Trambaiolo P, Pagnanelli A, Marini Grassetti M (2003) Emergency department ultrasonography impact on patient management and cost effectiveness. Minerva Med 94:347–352
21. Durston W, Carl ML, Guerra W (1999) Patient satisfaction and diagnostic accuracy with ultrasound by emergency physicians. Am J Emerg Med 17:642–646
22. Ward MJ, Sodickson A, Diercks DB, Raja AS (2011) Cost-effectiveness of lower extremity compression ultrasound in emergency department patients with a high risk of hemodynamically stable pulmonary embolism. Acad Emerg Med 18:22–31
23. Siu T, Chau H, Myhre D (2013) Bedside ultrasonography performed by family physicians in outpatient medical offices in Whitehorse, Yukon. Can J Rural Med 18:43–46
24. Taylor J, McLaughlin K, McRae A, Lang E, Anton A (2014) Use of prehospital ultrasound in North America: a survey of emergency medical services medical directors. BMC Emerg Med 14:6
25. Blaivas M, Kirkpatrick A, Sustic A (2007) Future directions and conclusions. Crit Care Med 35:S305–S307
26. Rüttimann S, Clémençon D, Dubach UC (1992) Does routine ultrasonography of the abdominal organs affect the subsequent management of the patient? Schweiz Med Wochenschr 122:1952–1954
27. Brenner DJ, Hall EJ (2007) Computed tomography—an increasing source of radiation exposure. N Engl J Med 357:2277–2284
28. Woolf SH, Johnson RE (2005) The break-even point: when medical advances are less important than improving the fidelity with which they are delivered. Ann Fam Med 3:545–552