Budget Impact Analysis of a Biosynthetic Mesh for Incisional Hernia Repair

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ABSTRACT

Purpose: With the development of newer prostheses for hernia repair, it is nowadays difficult to understand the total cost of managing patients treated with these advanced medical devices, especially in the complex abdomen, in which various complications may occur. The aim of this study was to determine the economic implications of these prostheses in order to inform decision making in the management of incisional hernia repair.

Methods: A budget impact analysis model was developed to evaluate the economic consequences related to the management of patients undergoing complex (Centers for Disease Control and Prevention wound class II–III or Ventral Hernia Working Group grade 2/3) incisional hernia repair through biosynthetic, synthetic, or biological meshes, from the hospital perspective in Italy. The model was populated with complication rates mainly retrieved from the literature to compare the current scenario with 60%, 10%, and 30% rates of synthetic, biosynthetic, and biological mesh utilization, respectively, with future hypothetical scenarios that consider increasing rates of biosynthetic mesh utilization with respect to the other types of mesh in the next 5 years. Hospital costs of the different events were estimated based on health care resource consumption derived from an electronic survey addressed to key opinion leaders in the field.

Findings: The analysis compared the current scenario with future hypothetical scenarios that consider increasing utilization rates of biosynthetic meshes of 25%, 38%, and 44% in the next 1, 3, and 5 years, as estimated by clinicians. Considering 40,000 incisional hernia repairs per year, an increasing use of the biosynthetic meshes may result in a decrease in the total hospital budget of about €153 million in the next 5 years, with a savings per patient of about €770.

Implications: The findings of this study support the use of biosynthetic meshes for complex abdominal wall repairs in Italy, showing a potential decrease in the hospital budget in Italy after the diffusion of the new biosynthetic prostheses. Further studies and data from clinical practice would provide additional information to increase the understanding of the

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economic sustainability of these advanced devices. (*Clin Ther*. 2018; 40:XXX–XXX) © 2018 Elsevier HS Journals, Inc. (*Clin Ther*. 2018;■:1–19)

Key words: budget impact, economic evaluation, incisional hernia, mesh, prosthesis.

INTRODUCTION

In the past 20 years, there have been changes in the treatment of hernias via abdominal wall surgery. Numerous improvements have been reported with innovations including the introduction of laparoscopy and tension-free, sutureless repair techniques with the use of prostheses, or so-called *meshes*. Today the use of prosthetic materials (in open and laparoscopic surgery) has almost completely replaced direct suture procedures, thus contributing to a decrease in the rate of recurrence.[1]

On the market, there are different types of prosthesis and fixation methods used in the repair of hernias in the abdominal wall. The most suitable type of prosthetic material can be chosen from among the following groups:

- *Synthetic nonabsorbable or partially absorbable material*: will remain in the body indefinitely and is considered a permanent implantation; it is used to provide permanent reinforcement to the repaired hernia.
- *Biosynthetic material*: constitutes a new class of materials that are completely absorbed by the surrounding tissue over time, also replacing the tissue as a scaffold.
- *Biological material*: "transforms" itself into the tissue with which it comes in contact. This concept is supported by findings from studies in animal tissues, which, after implantation, gradually replaced and "colonized" the material, so that the material disappeared completely after having exercised its containment effect for the necessary time.

When implanted into tissue, synthetic nonabsorbable or partially absorbable materials, being extremely compatible with tissue, act as foreign bodies, creating a scar reaction around the prosthesis itself. The use of these materials has become a proven success in the treatment of abdominal wall hernias, especially due to the low risk for recurrence.[2]

Biological and biosynthetic tissues are the result of the most recent studies in the field of abdominal wall repair. They are considered reshapeable because, after implantation, they are replaced, through a process of incorporation, by a new tissue formed at the site where the prosthesis is positioned and which has the anatomic and functional characteristics of the original one. In the patient, no trace of the prosthesis remains, but a "new" tissue is regenerated. These materials are now widely employed in cases of abdominal wall hernias at risk for infection, but their routine use is still limited because there are no robust scientific studies proving their effectiveness, especially concerning the risk for hernia recurrence, even many years after the intervention.[3] On the other hand, the literature in this setting reports a number of prospective or retrospective studies investigating the effectiveness profile of specific types of meshes, and further analyses or meta-analyses based on all of the available evidence, including data from registries, may be advisable in order to identify whether a particular mesh may perform better than others.

The considerable variety of materials and surgical techniques gives the surgeon the opportunity to choose the most appropriate technology in each individual patient, according to a "tailored surgery" approach.

The surgical technique and the materials used to close abdominal wall incisions are also of the utmost importance to avoid a high frequency of incisional hernias.[4] Incisional hernias are those formed on a surgical scar. It is a common postoperative complication following abdominal surgery, with a prevalence varying generally between 2% and 50%, but extreme values ranging from 0 to 91% have also been reported in the literature.[5] This wide variability may have resulted from a lack of accuracy in reporting, each surgeon's ability, the different periods of follow-up, and/or the heterogeneity (risk stratification) of the cohort of patients included in the studies.

With the development of newer meshes and approaches to hernia repair, it can be difficult to understand the total cost of use of these advanced medical devices. A recent systematic literature review[6] highlighted that there is a paucity of studies evaluating the cost of incisional hernia repair. That review showed that significant heterogeneity in time periods, surgical approaches, and cost items considered in few published studies make it difficult to combine the data needed for a quantitative evaluation.

The aim of the present article was to develop knowledge about the clinical and economic implications of the prostheses available for abdominal incisional hernia repair, for the purpose of supporting decision making by "stakeholders" in the hospital setting in Italy. The evaluation took into account the various aspects of the management of patients undergoing incisional hernia repair, including the approaches to the management of complications.

Although few studies have assessed the cost-effectiveness of different surgical approaches, to our knowledge, no studies have presented a budget impact analysis (BIA), which is an essential component of a complete economic assessment of any health care technology. The main objective of this research was to perform a BIA, updating a model presented previously,[7] in order to estimate the current economic impact of the management of patients with complex incisional abdominal hernia through biosynthetic mesh implants, synthetic or biological meshes, from the perspective of the hospital in Italy. The BIA was also performed to evaluate changes in the hospital budget, considering a future scenario with increased utilization of biosynthetic meshes in the next 5 years.

In the preliminary phase of the study, a systematic literature review was performed in order to derive clinical evidence on the 3 types of prostheses considered, as better specified in the Materials and Methods section.

MATERIALS AND METHODS

Data on the clinical efficacy of the 3 types of devices were derived from the published literature and integrated with data from clinical practice regarding the use of biosynthetic meshes. Cost data were estimated based on the use of specific health care resources for primary repair and for the management of main complications. Data on health care resource consumption associated with each item were derived from questionnaires addressed to opinion leaders in the field. The analysis of the complications was focused on recurrence, infected mesh removal, infection (superficial, deep, or involving organ space), and seroma, as these are the clinical outcomes generally considered by surgeons for measuring the success of the procedure.[8]

Literature Review and Clinical Data Synthesis

Clinical studies may classify the wounds of patients according to 1 of 2 classification systems: (1) the Ventral Hernia Working Group (VHWG) 2010 classification[9] or (2) the newer VHWG 2012 modification.[10] The first one assigns a growing risk, from grades 1 to 4, for developing a surgical site occurrence based on patient and wound characteristics (grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected), while the second one stratifies patients on the basis of wound contamination according to Centers for Disease Control and Prevention (CDC) classification[11] (class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected). Wounds classified as CDC class I (clean) may be classified as VHWG 2012 grade 1 (clean cases; no comorbidity) or 2 (clean cases + comorbidity, history of infection), while CDC clean-contaminated, contaminated, and infected wounds would be VHWG 2012 grade 3.[12]

The VHWG 2010 classification suggests the use of synthetic mesh for low-risk defects (grade 1) and biological mesh for higher-risk defects (grade 2) and contaminated or infected wounds (grades 3 and 4). However, given the significantly higher acquisition cost of biological meshes compared to synthetic ones, often there is a shift toward choosing synthetic mesh even in case of wound contamination.[13] On the other hand, biosynthetic meshes have shown promising results in CDC class II/III (high-risk) wounds.[14,15]

A systematic literature review was performed in February 2018 to retrieve clinical studies reporting on complications related to the use of biological, biosynthetic,* and synthetic meshes in complex abdominal wall repair.

The search focused on studies presenting data collected after the year 2000 and that considered grades 1 to 3 of both the VHWG 2010 and CDC classifications, since clinicians generally choose among the 3 types of prostheses in this setting. Only studies with at least 15 patients and 18 months of follow-up (mean or median) were considered. The search strategy is presented in the Appendix in the online version at https://doi.org/10.1016/j.clinthera.2018.09.003.

* With regard to biosynthetic meshes, we refer to Phasix® (Davol Inc, Warwick, RI, a subsidiary of CR Bard).

Data from Clinical Practice

As more importance is given to the collection and analysis of data from clinical practice for the evaluation of costs and outcomes associated with medical devices,[16] the multicenter registry "Italian Hernia Club" collects data on the biosynthetic mesh from 10 clinical centers in Italy (AO Universitaria Pisana, Pisa; Azienda Ospedaliero Universitaria, Ferrara; Città della salute, Ospedale Molinette, Torino; CTO, Azienda Ospedaliera dei Colli, Napoli; Ospedale Monaldi, Azienda Ospedaliera dei Colli, Napoli; Ospedale NOCSAE, Baggiovara, Modena; Ospedale S. Maria degli Ungheresi, Polistena; Ospedale San Paolo, Milano; Ospedale Santa Maria della Misericordia, Udine; Policlinico S. Orsola-Malpighi, Bologna, Week Surgery, Sede di Budrio). This registry was used, in addition to the literature search, to retrieve the frequencies of the main complications associated with incisional hernia repair (recurrence, removal of infected mesh, superficial infection, deep infection, organ infection, and seroma).

Health Care Resource Consumption and Costs

The analysis was performed from the perspective of the hospital, and the production and cost function for the provision of the health care services was considered (year-2017 euros; €1 = US $1.17). In particular, the cost function refers to the following direct-cost components: cost of drugs/treatments, cost of surgical materials, and cost of health care personnel. Indirect and general costs were not considered as they are not different among the alternatives compared.

Clinical pathways and health care resource consumption in the management of complications were estimated using data from a study-specific questionnaire administered to key opinion leaders in the field, affiliated with 12 hospitals in Italy, with great experience on mesh implants. On the basis of their clinical experience, clinicians were asked to estimate health care utilization. All of the clinicians received an electronic version of the questionnaire between January 24, 2017, and February 10, 2017. The questionnaire included the following sections:

- Introduction describing the patients' characteristics;
- Relevant examinations, laboratory tests, visits, drugs, and surgical materials related to hernia repair intervention, with personnel time for the different figures involved in the health care services and in the surgical activity; costs of drugs and surgical materials, including meshes;
- Management of main complications: recurrence, infected mesh removal, infection (superficial, deep, organ space), and seroma; data collection relates to examinations, laboratory tests, visits, drugs, negative-pressure wound therapy, hospitalizations, and related mean durations; and the costs of drugs and surgical materials, including meshes;
- Future scenarios of mesh use, including a forecast of possible future (1, 3, and 5 years) scenarios of the utilization of the 3 types of mesh in Italy.

Hospital costs were assigned to each health care resource reported (health care personnel time for surgery/visits/examinations, surgical materials, drugs, negative-pressure wound therapy, hospitalizations for complications). Health care professionals' time was monetized based on their wages. During hospital stays for the management of complications, the DRG (Diagnosis Related Group) reimbursement was considered a proxy for hospital cost. In this case we referred to DRG 453 (Complications of Treatment) for seroma, DRG 418 (Postoperative and Posttraumatic Infections) for superficial infection, and DRG 572 (Gastrointestinal and Peritoneal Infections) for deep/organ space infection. In cases of hospitalization for infection leading to treatment in a critical care unit, we referred to DRG 575 (Septicemia with Mechanical Ventilation 96 + hours, age >17 years).

Missing data were replaced with mean values calculated from the available reported data on material costs and health care personnel time. When data on hospital costs of drugs were missing, a search of the Pharmaceutical Database (http://www.federfarma.it), which reports cost data from the National Healthcare Service of Italy, was performed.

Finally, in each cost category, a weighted mean was calculated on the basis of the number of survey responders.

Budget Impact Analysis

A BIA model was developed to compare the current scenario with 60%, 10%, and 30% rates of synthetic, biosynthetic, and biological mesh utilization, respectively, with future hypothetical scenarios considering increasing rates of biosynthetic mesh utilization, with respect to the other types of mesh, in

the next 5 years. The estimation of current and new scenarios, including an increased proportion of biosynthetic meshes in the next years, was based on key opinion leaders' replies to the questionnaire. In this regard, recent (2015–2016) data on expenditure for medical devices in public hospitals, provided by Italy's Ministry of Health (MoH), were analyzed in order to evaluate the reliability of the assumptions about the current scenario.

We assumed that the costs of infected mesh removal, infection, and seroma were sustained in the first year after hernia repair, while costs for recurrences were related to the second year.

In order to perform the BIA, a review of epidemiologic data focused on patients undergoing incisional hernia repair in Italy was carried out.

The costs of the current and new scenarios were determined by multiplying the cost of each strategy by the proportion of the eligible population using it, taking into account subsequent yearly incident cohorts. Financial streams are presented as undiscounted costs, since the focus of the analysis was the expected budget at each point.[17]

A few scenario analyses were performed to test the robustness of the model results according to variations of the main model parameters.

RESULTS

Literature Review and Clinical Data Synthesis

Table I reports the studies retrieved by the literature search, with the characteristics and frequencies of complications. Since different studies considered a population mix, with wound classification ranging from classes I to III (CDC) or grades 1 to 3 (VHWG), we considered 2 scenarios in the analyses: (1) an *extended scenario*, with patients with wound classification ranging from classes I to III (CDC) or from grades 1 to 3 (VHWG); and (2) a *restricted scenario*, with patients with wound classification limited to classes II and III (CDC) and to grades 2 and 3 (VHWG). The extended scenario considers the extended setting of the use of meshes in clinical practice, while the restricted scenario represents the recommended setting for the use of the biosynthetic mesh (recommended for use in complex patients).

As the retrieved evidence was not from randomized, controlled trials but from retrospective or prospective studies, the meta-analyses of the 3 types of mesh (Stata software, metaprop command) were performed considering single-arm frequencies of the different complications and distinguishing the extended and restricted scenarios (Table II).

The same 2 scenarios were considered in the clinical-practice data on the biosynthetic mesh: scenario A presented 47 patients with 21.3% superficial infections, 14.9% seromas, 4.3% infected mesh removals, and 0 recurrences, deep infections, and organ space infections, while scenario B reported 43 patients with 23.3% superficial infections, 16.3% seromas, 4.7% infected mesh removals, and 0 recurrences, deep infections, and organ space infections.

Health Care Resource Consumption and Costs

Eight of 12 centers, involving a total of 13 opinion leaders, completed the questionnaire, representing institutions with the highest volumes of treated patients in Italy. The estimated health care resource utilization is reported in Supplemental Table I in the online version at https://doi.org/10.1016/j.clinthera.2018.09.003.

Costs related to health care resource consumption are summarized in Table III. Table IV reports the mean cost per patient, calculated including the cost of hernia repair, the mesh cost, and the cost of the management of the complications, weighted according to the complication frequencies reported in Table II. The mean cost of mesh in cases of recurrence was €2401 per patient, estimated by taking into account the mean cost of the mesh used (synthetic, €1322; biosynthetic, €3053; and biological, €6552), weighted for the percentage of use (synthetic, 67%; biosynthetic, 19%; biological, 14%). These costs are higher than the ones used for the primary intervention since larger meshes are used in cases of recurrence.

Budget Impact Findings

The BIA model was quantified with health care resource consumption and costs estimated from the earlier-cited electronic surveys. The analysis compared the current scenario with future hypothetical scenarios and considered increasing rates of biosynthetic mesh utilization of 25%, 38%, and 44% in the next 1, 3, and 5 years, as estimated by clinicians.

The expenditures, provided by Italy's MoH, of the different types of mesh were analyzed in order to obtain comparative data on the current market share. The expense distribution from 2015–2016 was 85%, 2% to 3%, and 12% to 13% with synthetic, biosynthetic, and biological mesh, respectively. It

Table I. Study characteristics and complication rates.

Type of Mesh/ Study	Follow-up Duration, mo	Study Type	Period	Population	No. of Patients	Recurr., %	Infected Mesh Removal %	Superf. Infect., %	Deep Infect., %	Organ Space Infect., %	Seroma, %
Biosynthetic*											
Buell 2017[18,†]	18 (mean)	Retrospective, comparative, single center	2010–2015	VHWG grade 2	31	6.5	–	–	–	–	–
Novitsky 2016[19]	18 (mean)	Prospective, single arm, multicenter	2014	CDC class I, 68%; class II, 20%; class III, 12%	25	4.0	–	12.0	8.0	–	4.0
Plymale 2017[20,†]	24 (mean)	Prospective, comparative, single center	NA	Matched population[‡]	31	0	–	–	–	–	–
Roth 2017[15,†]	18 (mean)	Prospective, single arm, single center	NA	VHWG grade 2	121	9.1	–	–	–	–	6.6
Synthetic											
Köhler 2015[22,†]	28 (mean)	Retrospective, single arm, single center	2009–2013	VHWG grade 2/ 3	108	8.3	3.7	–	–	3.7	–
De Noto 2013[21,†]	18 (mean)	Retrospective, comparative, multicenter	2008	VHWG grade 3	268	23.1	22.8	–	–	–	5.6
Koscielny 2018[23]	27.3 (mean)	Retrospective, comparative, single center	2009–2013	CDC class I, 8%; class II, 50%; class III, 42%	24	12.5	–	8.3	12.5	–	20.8
Krpata 2013[13,†]	18 (mean)	Retrospective, single arm, single center	2006–2011	VHWG grade 2	88	4.5	2.3	–	–	–	2.3

Liang 2014[24]	61 (median)	Retrospective, comparative, single center	2000–2011	VHWG grade 1–3 (12.5% grade 1)	40	22.5	–	25.0	12.5	5.0	7.5
Majumder 2016[25,†]	20 (mean)	Retrospective, comparative, multicenter	2009–2015	CDC class II, 65%; class III, 35%	57	7.0	1.8	5.3	5.3	1.8	3.5
Novitsky 2016[26]	31.5 (mean)	Retrospective, single arm, single center	2006–2014	CDC class I, 66%; class II, 26%; class III, 8%	428	–	–	6.5	2.6	–	2.6
Plymale 2017[20,†]	24 (mean)	Prospective, comparative, single center	NA	Matched population[‡]	51	7.8	–	–	–	–	–
Souza 2013[27]	23 (median)	Retrospective, single arm, single center	2005–2010	VHWG grades 1–3 (22% grade 1)	87	5.7	–	–	–	–	1.1
Abdelfatah 2015[28,†]	60 (mean)	Retrospective, single arm, single center	2004–2008	Subpopulation CDC class II/III	26	65.4	23.1	–	–	–	–
Biological											
Buell 2017[18,†]	18 (mean)	Retrospective, single center	2010–2015	VHWG grade 2	42	23.8	–	–	–	–	–
De Noto 2013[21,†]	18 (mean)	Retrospective, comparative, multicenter	2008	VHWG grade 3	56	16.1	3.6	–	–	–	1.8
Hood 2013[29,†]	20 (mean)	Retrospective, single arm, single center	2008–2011	CDC class II	68	1.5	–	30.9	0	–	8.8
Koscielny 2018[23]	23.5 (mean)	Retrospective, comparative, single center	2009–2013	CDC class I, 8%; class II, 50%; class III, 42%	24	25.0	–	12.5	12.5	–	29.2
Majumder 2016[25,†]	20 (mean)	Retrospective, comparative, multicenter	2009–2015	CDC class II, 65%; class III, 35%	69	21.7	2.9	5.8	21.7	4.3	4.3

(*continued on next page*)

Table I. (*Continued*)

Type of Mesh/ Study	Follow-up Duration, mo	Study Type	Period	Population	No. of Patients	Recurr., %	Infected Mesh Removal %	Superf. Infect., %	Deep Infect., %	Organ Space Infect., %	Seroma, %
Plymale 2017[20,†]	24 (mean)	Prospective, comparative, single center	NA	Matched population[‡]	44	18.2	—	—	—	—	—

Centers for Disease Control and Prevention (CDC) classification of wound characteristics: class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected. Ventral Hernia Working Group (VHWG) classification: grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected.

* Phasix® (Davol Inc, Warwick, RI, a subsidiary of CR Bard).

† Studies considered in the restricted scenario.

‡ Plymale 2017[20] presented results from matched populations that underwent ventral incisional hernia repair with the 3 types of meshes. The populations were matched according to age, body mass index, sex, wound class, and comorbidities.

Table II. Meta-analysis of different complication rates for the three kinds of meshes. Data are given as mean (95% CI) percentages.

Complication	Extended Scenario: CDC Wound Class I–III or VHWG Grade 1–3			Restricted Scenario: CDC Wound Class II/III or VHWG Grade 2/3		
	Synthetic Mesh	Biologic Mesh	Biosynthetic*	Synthetic Mesh	Biologic Mesh	Biosynthetic*
Recurrence	10.6 (5.4–17.2)	21.6 (9.5–36.6)	3 (0.1–8.5)	9.8 (3.6–18.5)	21.2 (8.1–38)	2.8 (0–9.5)
Infected mesh removal	6.2 (0.1–19)	7.2 (0.5–19.1)	4.3 (0.5–14.5)	6.2 (0.1–19)	7.2 (0.5–19.1)	4.7 (0.6–15.8)
Superficial infection	9.6 (3.5–17.9)	15.2 (2.4–35.1)	17.8 (9.5–27.8)	5.3 (1.1–14.6)	16.4 (10.5–23.1)	23.3 (11.8–38.6)
Deep infection	6.3 (1.5–13.5)	8.3 (0–31.5)	1.2 (0–6)	5.3 (1.1–14.6)	6.9 (3–11.9)	0 (0–8.2)
Organ space infection	3.2 (1–6.3)	4.3 (0.9–12.2)	0 (0–0.75)	2.9 (0.7–6.3)	4.3 (0.9–12.2)	0 (0–8.2)
Seroma	3.8 (1.7–6.6)	8.0 (1.6–17.9)	8.0 (3.3–14.2)	4.4 (2.5–6.6)	4.8 (1.6–9.3)	8.6 (4.6–13.6)

Centers for Disease Control and Prevention (CDC) classification of wound characteristics: class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected. Ventral Hernia Working Group (VHWG) classification: grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected.

* Phasix® (Davol Inc, Warwick, RI, a subsidiary of CR Bard).

Table III. Summary of the main cost items. Data are given as mean cost per patient (year-2017 euros).

Cost Type	Incisional Hernia Intervention	Recurrence Intervention	Infected Mesh Removal	Superficial Infection	Deep Infection	Organ Space Infection	Seroma
Health care personnel—visits/examinations	161	161	187	180	255	160	70
Hospital drugs	132	132	132	8	—	—	—
Consumables, mesh excluded	423	423	259	—	—	—	—
Health care personnel—surgery	332	367	400	—	—	—	—
Negative-pressure wound therapy	—	—	—	45	56	217	—
Hospitalizations	—	—	—	62	1593	5400	23
Total	1048	1083	978	296	1904	5777	93

should be noted that from these data it was not possible to distinguish the use of prostheses, and in particular whether a mesh was used for a hernia intervention or for an incisional hernia repair, which is the specific setting of the present analysis. The high percentage of use of synthetic mesh derived from the MoH data was likely due to the use of these types of mesh in the majority of hernia surgeries, while for incisional hernia repairs more advanced devices (biological and biosynthetic meshes) are used, due to the particular complexity of this kind of intervention.[3] Moreover, in 2017 the use of biosynthetic mesh more than doubled in comparison to 2016 according to involved clinicians, highlighting the need for more updated data. Due to the limitation of this analysis, we preferred to rely on data estimated by clinicians and to present a sensitivity analysis that adopted the expense distribution derived from the MoH data.

Considering 40,000 incisional hernia repairs per year,[30] an increasing use of the biosynthetic mesh may result in decreases in the total hospital budget in the next 5 years of €161.1 million in the extended scenario and €153.5 million in the restricted scenario (Table V), showing a savings per patient of about €770 in the next 5 years.

In the setting of diminished future rates of biosynthetic mesh utilization (year 1, 15%; year 3, 20%; and year 5, 25%, with redistributed values of the other meshes proportionally to the values of the current scenario), savings would be €11.0 and €13.1 million in the restricted and extended scenarios, respectively, with a savings per patient of about €55 to €65 in the next 5 years. Assuming double the prevalence rate of complications for biosynthetic meshes, the savings would become €129.4 and €138.1 million in the restricted and extended scenarios, respectively, showing a savings per patient of about €650 to 690€ in the next 5 years.

Assuming the current scenario based on the distribution of expenses from MoH data in 2016 (synthetic, 85%; biosynthetic, 3%; and biological, 12%), the model showed incremental expenses in the next 5 years of about €39 and €33 million in the restricted and extended scenarios, respectively, showing an additional cost per patient of about €165 to €195 in the next 5 years.

A set of univariate sensitivity analyses was performed by varying input costs. In particular, minimal and maximal values reported by clinicians of the main cost categories were used to inform the model. The results are summarized in Table VI. Greater variations in the model results are reported for variations of costs of the management of recurrences and deep infections.

The findings from these analyses suggest that variations in the market share in the current and future scenarios can greatly influence the model results.

DISCUSSION

Surgical repair with mesh implantation is considered the method of choice for the management of patients with incisional hernia.[31] Patients undergoing incisional hernia repair entail a substantial economic burden on

Table IV. Summary of mean costs for patient management for the different meshes for the different scenarios (extended and restricted). Data are given as euros.

Cost Type/Scenario	Synthetic Mesh	Biologic Mesh	Biosynthetic Mesh
Mesh	1007	5542	2523
Hernia intervention	1048	1048	1048
Recurrence, meshes: 67% synthetic, 19% biosynthetic, 14% biologic			
Extended	369	752	105
Restricted	341	665	98
Infected mesh removal + re-intervention (biologic mesh)			
Extended	469	469	322
Restricted	469	469	356
Superficial infection			
Extended	28	45	53
Restricted	16	50	69
Deep infection			
Extended	120	158	23
Restricted	101	154	—
Organ space infection			
Extended	185	251	—
Restricted	168	248	—
Seroma			
Extended	4	7	7
Restricted	4	4	8
Mean cost per patient			
Extended	3230	8348	4080
Restricted	3154	8180	4100

Extended scenario, patients with wound classification ranging from Centers for Disease Control and Prevention (CDC) classes I to III or from Ventral Hernia Working Group (VHWG) grades 1 to 3. Restricted scenario, patients with wound classification limited to CDC class II/III and to VHWG grade 2/3. CDC classification of wound characteristics: class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected. VHWG classification: grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected.

the health care system, as complications such as recurrence or infections may develop and result in additional hospitalizations and morbidity. Although different prostheses are available with various characteristics in terms of medical tolerability, functionality, and performance, there is currently no robust consensus as to which mesh type is the best.[3,32] The VHWG tried to develop a grading scale for use in selecting the appropriate surgical technique, repair material, and overall clinical approach to the patient. Although it is commonly used among surgeons, it is a nonvalidated instrument.

A recent study performed a comparison of synthetic mesh versus acellular dermal matrix in clean-contaminated ventral hernia repair through a decision model with a lifetime perspective.[33] Synthetic mesh reinforcement had an expected cost of $15,776 (21.03 quality-adjusted life-years), while biological mesh had an expected cost of $23,844 (20.94 quality-adjusted life-years). Sensitivity analysis demonstrated that synthetic mesh was the preferred and most cost-effective strategy in 94% of simulations, supporting its overall greater cost utility. Regardless, this conclusion seems in contrast with the

Table V. Budget impact analysis in the restricted scenario.

Year	Synthetic Mesh			Biosynthetic Mesh			Biologic Mesh			Total Budget Impact	Incremental Savings in Comparison to Current Scenario
	Market Share,%	Users Cohort	Cost,€	Market Share,%	Users Cohort	Cost,€	Market Share,%	Users Cohort	Cost,€		
Current scenario											
0	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
1	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
2	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
3	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
4	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
5	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	—
Future scenario											
0	60	24,000	75,684,743	10	4000	16,400,990	30	12,000	98,159,730	190,245,464	0
1	62	24,857	78,095,170	25	10,000	40,417,275	13	5143	46,630,632	165,143,077	25,102,387
2	62	24,857	78,387,770	25	10,000	41,002,476	13	5143	42,068,456	161,458,701	28,786,762
3	54	21,714	69,549,540	38	15,143	61,587,863	8	3143	27,039,135	158,176,538	32,068,925
4	54	21,714	68,476,673	38	15,143	62,089,463	8	3143	25,708,501	156,274,636	33,970,827
5	49	19,714	62,852,345	44	17,714	72,382,157	6	2571	21,414,409	156,648,911	33,596,553
Total incremental savings											153,525,455

Restricted scenario, patients with wound classification limited to Centers for Disease Control and Prevention (CDC) class II/III and to Ventral Hernia Working Group (VHWG) grade 2/3. CDC classification of wound characteristics: class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected. VHWG classification: grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected.

Table VI. Univariate sensitivity analyses in the extended (A) and restricted (B) scenarios according to cost-input variations.

Cost Type	Value			Savings in the next 5 y		
	Low	Base–Case	High	Low	Base–Case	High
Intervention	302	1048	2325	A: 160,082,447 B: 152,988,655	A: 161,083,376 B: 153,525,455	A: 162,797,144 B: 154,445,215
Recurrence	1815	3483	5428	A: 150,971,507 B: 144,645,135	A: 161,083,376 B: 153,525,455	A: 172,870,776 B: 163,876,618
Infected mesh removal management (mesh removal + re-intervention with biologic mesh)	6817	7567	8989	A: 160,076,056 B: 152,985,127	A: 161,083,376 B: 153,525,455	A: 162,991,409 B: 154,548,967
Superficial infection management	6	296	1202	A: 161,560,366 B: 154,666,836	A: 161,083,376 B: 153,525,455	A: 159,589,413 B: 149,952,887
Deep infection management	17	1904	4265	A: 154,922,550 B: 146,565,487	A: 161,083,376 B: 153,525,455	A: 168,791,748 B: 162,232,111
Organ space infection management	1359	5777	9001	A: 152,226,082 B: 144,848,274	A: 161,083,376 B: 153,525,455	A: 167,547,631 B: 159,857,162
Seroma management	26	93	274	A: 161,103,662 B: 153,663,714	A: 161,083,376 B: 153,525,455	A: 161,029,047 B: 153,153,613

Extended scenario, patients with wound classification ranging from Centers for Disease Control and Prevention (CDC) classes I to III or from Ventral Hernia Working Group (VHWG) grades 1 to 3. Restricted scenario, patients with wound classification limited to CDC class II/III and to VHWG grade 2/3. CDC classification of wound characteristics: class I = clean; class II = clean-contaminated; class III = contaminated; and class IV = dirty-infected. VHWG classification: grade 1 = low risk; grade 2 = comorbid; grade 3 = potentially contaminated; and grade 4 = infected.

VHWG's clinical recommendations, which endorse biological meshes for use in clean-contaminated fields.[9]

A recent study suggested that mesh reinforcement can be effectively and safely used to decrease the prevalence of incisional hernia in patients undergoing laparotomy.[34] In addition, together with patients after open surgery, this advantage also remained evident in patients undergoing laparoscopic surgery. Ideally, a perfect preoperative risk model can accurately estimate the possibility of incisional hernia formation and provide evidence-based recommendations on prophylactic mesh placement. In high-risk patients, mesh reinforcement may be effective and well-tolerated in preventing the formation of incisional hernia after abdominal surgery, and, consequently, it is likely to avoid future costs.

We show that in incisional hernia repair, an increasing use of the biosynthetic mesh may result in a savings per patient of about €770 in the next 5 years, considering the hospital's perspective. This result should be considered cautiously since the study presents a few limitations. First, the scenario analysis performed on data from the BIA model showed that savings are mainly based on the assumptions on current market share and high future utilization rates of biosynthetic meshes over the other types of prostheses, as estimated by clinicians; lower future utilization frequencies may lead to more contained savings, while a limited use in the current scenario of biological and biosynthetic meshes may lead to incremental hospital costs in the future. A continuous monitoring and analysis of the use of these prostheses could give insight into better estimation of present and future utilization trends.

The data on complication rates were retrieved from a limited number of studies with different durations of follow-up (18–61 months), numbers of patients (24–428), and a combination of wound-classification grades. Moreover, the rates of events varied across the studies, and the calculated weighted means may not have been fully representative of the scenario in Italy. In addition, the best option for synthesizing the available evidence would have been a formal meta-analysis that considered the relative risks for each complication. Regardless, all considered studies were not randomized, controlled trials but were retrospective or prospective studies, and next-best option of performing meta-analyses based on single-arm data was applied. In the future, powerful techniques, such as network meta-analyses, could be applied in order to obtain more robust results.

With regard to the estimation of health care resources, it must be noted that data derived from physician-reported questionnaires may be limited by varying recollection and poor generalizability. Variables derived from prospective, multicenter, observational studies would increase the validity of the current model. Using data from observational studies in addition to randomized controlled trials would also serve to support the clinical evidence of the comparative effectiveness of the meshes.

The present analysis focused only on clinical outcomes, which gives an indication of the success of the procedure. Regardless, the literature reports a prevalence of chronic pain of 7%–41% following ventral hernia repair.[8] A broader analysis taking into account also chronic pain and patients' functional status would be desirable to give a complete view of the costs of managing these conditions.

The study took into consideration only the hospital perspective. A study from France (Gillion et al [2016]),[6] which considered both direct and indirect costs, estimated a mean total cost of an incisional hernia repair of €6451, ranging from €4731 in unemployed patients to €10,107 in employed patients whose indirect costs were slightly higher than the direct costs. Considering that indirect costs represent >50% of the total cost in some patient categories, a broader analysis considering the societal perspective would give additional information on the sustainability of the use of the advanced prostheses.

CONCLUSIONS

In light of the paucity of cost (and cost-effectiveness) data from Italy, the present study adds evidence about the clinical and economic advantages of the use of biosynthetic meshes in complex incisional hernia repairs, but highlights the need for further studies or registries involving different types of meshes. In the future, prospective, randomized trials, or registries, of different mesh materials may facilitate a stronger level of recommendation. Ongoing and future analyses of the cost-effectiveness relationship, accounting for the expense of materials, surgical procedures potential complications, and indirect costs, would be greatly beneficial to practitioners and administrators.

CREDIT AUTHOR STATEMENT

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Carla Rognoni - Formal analysis;
Rosanna Tarricone - Funding acquisition;
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Rosanna Tarricone, Giorgio Soliani - Supervision;
Rosanna Tarricone, Giorgio Soliani - Validation;
Carla Rognoni - Visualization;
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CONFLICTS OF INTEREST

The authors have indicated that they have no conflicts of interest with regard to the content of this article.

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APPENDIX A. SUPPLEMENTARY DATA

SEARCH QUERIES

Synthetic meshes:

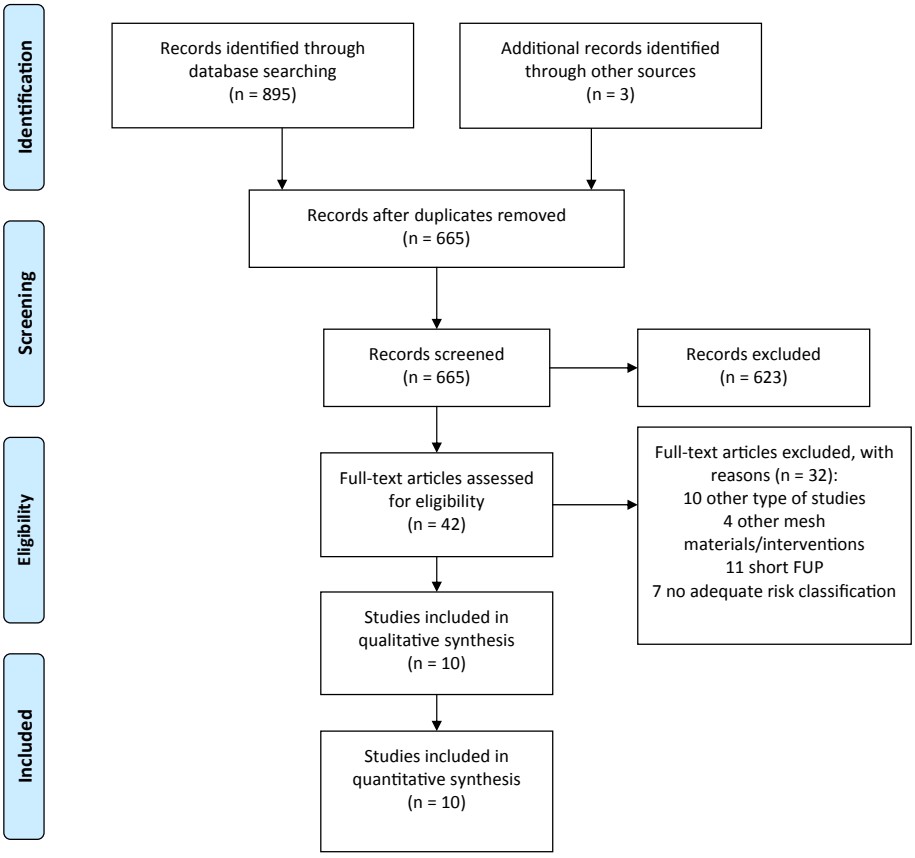
"synthetic mesh*" AND ("incisional hernia" OR "ventral hernia" OR ("major" AND "hernia") OR ("complicated" AND "hernia")) AND (complication* OR infection OR "surgical site occurrence" OR SSO)

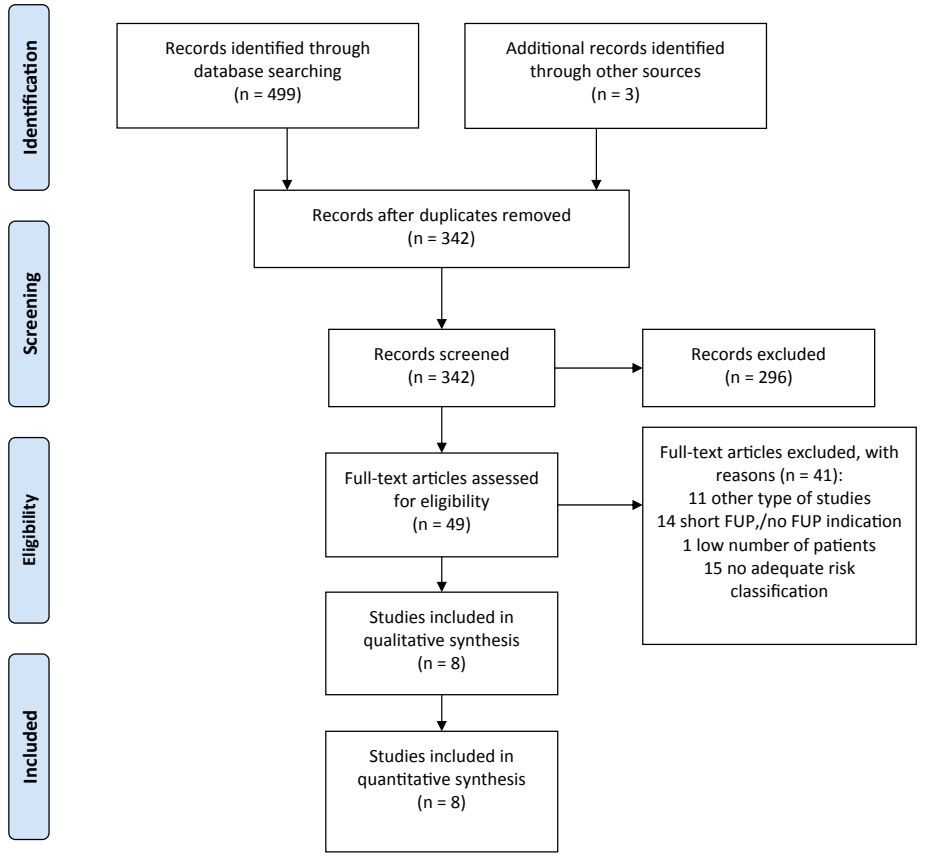
Biologic meshes:

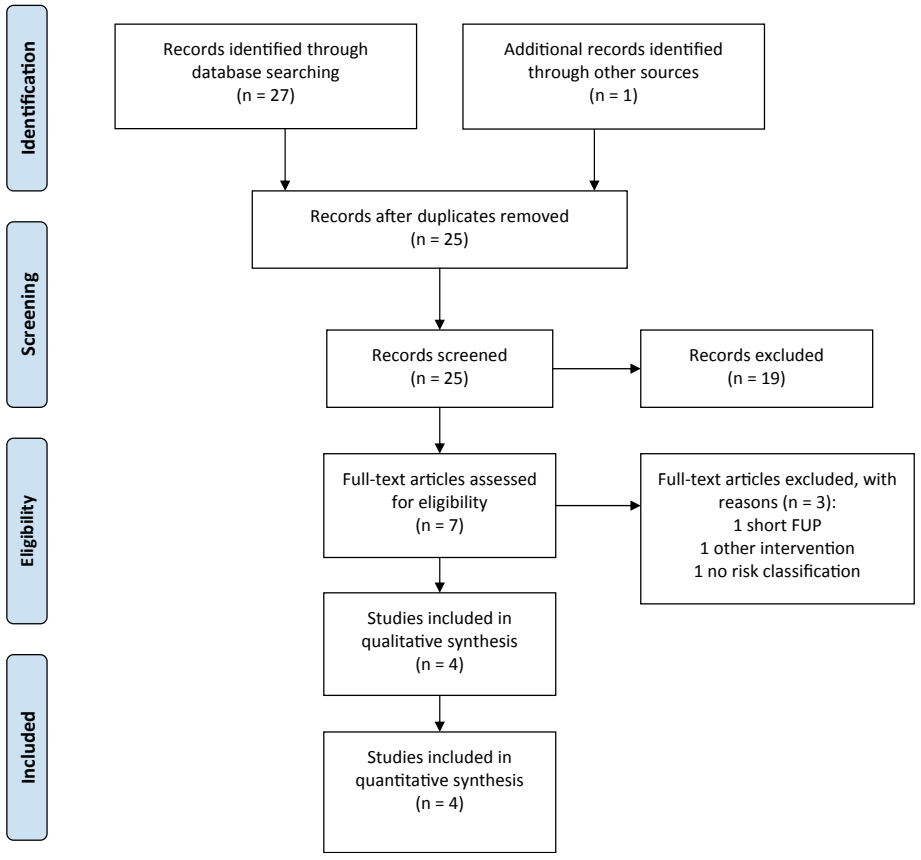
"biologic mesh*" AND ("incisional hernia" OR "ventral hernia" OR ("major" AND "hernia") OR ("complicated" AND "hernia")) AND (complication* OR infection* OR "surgical site occurrence" OR SSO)

Biosynthetic meshes:

("phasix" OR "poly-4-hydroxybutyrate" OR P4HB) AND ("incisional hernia" OR "ventral hernia" OR ("major" AND "hernia") OR ("complicated" AND "hernia")) AND (complication* OR infection* OR "surgical site occurrence" OR SSO).




Identification
Screening
Eligibility
Included
Records identified through database searching (n = 499)
Additional records identified through other sources (n = 3)
Records after duplicates removed (n = 342)
Records screened (n = 342)
Records excluded (n = 296)
Full-text articles assessed for eligibility (n = 49)
Full-text articles excluded, with reasons (n = 41):
11 other type of studies
14 short FUP,/no FUP indication
1 low number of patients
15 no adequate risk classification
Studies included in qualitative synthesis (n = 8)
Studies included in quantitative synthesis (n = 8)


Identification
Screening
Eligibility
Included
Records identified through database searching (n = 27)
Additional records identified through other sources (n = 1)
Records after duplicates removed (n = 25)
Records screened (n = 25)
Records excluded (n = 19)
Full-text articles assessed for eligibility (n = 7)
Full-text articles excluded, with reasons (n = 3):
1 short FUP
1 other intervention
1 no risk classification
Studies included in qualitative synthesis (n = 4)
Studies included in quantitative synthesis (n = 4)

Supplementary Table 1. Healthcare resource utilization.

Healthcare personnel (P=physician, N=nurse, T=technician) mean time per patient (minutes)

	Hernia repair/ recurrence			Mesh removal			Superficial infection			Deep infection			Organ space infection			Seroma		
	P	N	T	P	N	T	P	N	T	P	N	T	P	N	T	P	N	T
Visits																		
Anesthesiological	21	6		21	8													
Surgical	74	53		94	69		31	28		28	18		56	36		35	28	
Cardiologic	3	1																
Infectivologist				1														
Exams																		
Blood		17			18		6	12		16	10			20			2	
Culture																1	1	
ECG	8	11		5	10													
TC abdomen	21	16	3	25	20	4	7	6	1	18	14	4	41	36	5	1	1	
MRI abdomen	1	1		2	1		1	1										
Rx torax	10	11	2	9	10	3							2	2				
Echocardiogram	2																	
Abdominal ultrasound				1			2									10		
Treatments																		
Medications							67	92		149	149		35	35		7	7	
Negative-pressure wound therapy							8	19		38	38		4	4		4	4	

Surgery mean time per patient (minutes)

	Hernia repair	Recurrence	Infected mesh removal
Surgeon	128	143	161
Anesthetist	125	139	144
Scrub nurse	129	143	155
Operating room nurse	161	173	185

Negative-pressure wound therapy

	Superficial infection	Deep infection	Organ space infection
Mean number of disposables per patient	0.82	0.74	3.62

Hospital admissions — mean number of days per patient

	Superficial infection	Deep infection	Organ space infection	Seroma
Ordinary	0.28	6.52	13.95	0.08
Intensive care	—	0.02	1.26	—