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Review Article

Practical Concerns about the Metrics and Methods of Financial Outcome Measurement in Antimicrobial Stewardship Programs: A Narrative Review

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Abstract

Emerging pathogens in the meantime of paucity of new antibiotics discovery, put antimicrobial stewardship in the center of attention, to preserve the existing antimicrobial effect. Implementation of antimicrobial stewardship programs, however, needs approval from healthcare system managers. The approval process can be enhanced, when the beneficial effects of stewardship programs are supported by both clinical and financial evidence. Focusing on the financial outcome evaluation, the practitioners who run the stewardship programs, may choose certain methods and metrics, depending on the clinical setting scale and type, available human resources, and budget. The wise selection of the methods and metrics warrants a comprehensive insight of the existing methods and metrics, deployed by typically published works that set good examples to follow. This review is an attempt to provide such an insight along with typical relevant examples for each metric and method.

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What's Known

- Antimicrobial stewardship programs (ASPs) are necessary to preserve the efficacy of antibiotics and avoid microbial resistance.
- ASP outcomes can be evaluated in two different categories: clinical and financial outcomes.
- The financial evaluation of ASP outcomes has been studied in different scales, different methods, and different metrics.

What's New

- This study provides all important metrics and methods in a concise review. The researchers may find this review as a quick guide for selecting the suitable metrics and methods in their stewardship studies.
- Typical publications for each metric and method have been introduced in this review.

Introduction

The financial analysis of an antimicrobial stewardship program (ASP) is a great concern of healthcare managers, policymakers, and governments.[1] Clinicians may be more interested in the clinical outcomes and reduced microbial resistance in implemented ASPs,[2] but the implementation, or even the initiation of the program would be dependent on the anticipated positive financial benefit in many occasions. Using financial metrics to assess the ASPs is still challenging, due to the involvement of interwoven clinical objectives. Moreover, the positive financial impact of ASP may appear initially, but plateau after two to three years. Therefore, keeping the administration interested in running ASP would not be easy.[3]

Referring to the existing literature, an increasing number of published ASP projects with financial objectives can be retrieved. The researchers and practitioners often focus on certain metrics and methods, rather than a comprehensive and integrated analytical approach, due to the practical limitations in their clinical settings. Selecting the metrics and methods for forthcoming ASP projects requires a compact guide that brings all important metrics and methods together to enhance and improve both implementation and analysis of outcomes from the financial point of view. This is an attempt to provide a collection of all important metrics and methods of financial analysis of ASPs, using typical recent publications that represent a wide variety of the objectives, metrics, and methods. The researchers who plan for running ASP, will find this review a useful practical guide for selecting the most suitable endpoints and methods in their projects.

Previously, Naylor and colleagues tried to find out whether ASPs are cost-effective.[4] They used the following keywords in PubMed to look up the relevant resources: ((cost-effectiveness) OR (cost-benefit) OR (cost-utility) OR (cost effectiveness) OR (cost benefit) OR (cost utility) OR (cost saving)) AND ((antimicrobial stewardship) OR (antibiotic stewardship)).[5] We used the same search strategy for exploring the conducted research and publications in ASP with financial objectives from 2000 to 2021, to reveal the deployed methods and metrics of ASP implementation. The Scopus database was also searched, using similar keywords. The retrieved number of results from PubMed and Scopus was 613 and 2979, respectively. After screening the titles and abstracts and omitting the duplications, the most relevant publications were selected for this review (table 1).

In the first section of this review, the authors will provide an insight into the common financial metrics of ASP. The next section will discuss the methods by which the stated metrics can be measured.

Metrics

Cost

Cost is the most common interested financial metric in ASP studies. Besides, the clinical endpoints, reducing healthcare costs is a major objective of ASPs, without which it is hard to convince healthcare managers to adopt ASP. However, the evaluation and analysis of the impact of ASP on cost is not a straightforward matter.

The simplest approach is probably the comparison of antimicrobial cost before and after the implementation of ASP. Xiao and colleagues reported the impact of a nationwide national formulary restriction in China on the procurement and frequency of use of antibiotics during the 2010 to 2016 period.[41] The proportion of antibiotic to all drugs procurement dropped from 22% to 13% during this period, where the microbial resistance shows the desired profile. On a smaller scale, Sick and others conducted a retrospective cohort study that investigated the impact of an ASP in a pediatric hospital in a six-year period.[19] The intervention was a restriction policy on 33 antibiotics. The cost-saving was calculated using the below equation.

$$Cost\ Savings = (cost\ if\ 100\%\ approval) - (actual\ charge)$$
$$= \frac{restricted\ dose\ \times average\ charge\ per\ restricted\ dose}{average\ approval\ rate} - (restricted\ doses\ \times average\ charge\ per\ restricted\ doses)$$

Cost, however, is not limited to the direct cost of procurement of antimicrobials. A comprehensive cost analysis of ASP should include a variety of fixed, variable, potential, operational, and societal costs.

Fixed costs may vary with time, rather than the quantity of output, such as rental and staff salaries. On the other hand, variable cost alteration is a function of the level of output, such as food, service fees, and supplies.[49] Some of the authors have considered the fixed cost a synonym of indirect cost, where variable cost can be substituted with direct or marginal cost.[50] Examples of direct cost in the context of antimicrobial resistance in hospital settings, as outlined by Howard and colleagues, are general hospital costs per day/per bed (either by specialty or by department/ward), cost of patient isolation (supplies, housekeeping, waste disposal, increased portable testing services, and increased staffing), antimicrobial acquisition costs, antimicrobial administration costs, nursing staff time for specialized nurses, the occurrence of other infections and complications, the occurrence of other procedures, laboratory costs for screening procedures, physician staff time, infection control staff, lab testing for diagnosis.[51]

Actual versus potential cost is also discussed by some researchers.[52] Antimicrobial cost analysis, sometimes is about prospective cost evaluation, and the estimated inflation rate may be considered, where actual inflation rate might differ from anticipated ones, or a low-price generic product might be purchased, a drug shortage might be encountered, etc.

Implementation (operational) cost refers majorly to the staff wage and fringe benefits, allocated computers and software, pertinent maintenance costs, training sessions, and circulars/educational materials. It is probably the most important parameter from the viewpoint of managers, when they want to decide about running the program.[53] According to a systematic review, the type of intervention was primarily therapy evaluation and providing review and feedback in most of the reported ASPs (63%), followed by altered therapy guidelines (16%)

Table 1: Selected antimicrobial stewardship publications with financial objectives.

Author/Year	Metrics	Method
Pakyz 2009[6]	Carbapenems use as days of therapy per 1,000 patient days, incidence rate, and proportion of carbapenem-resistant *P. aeruginosa* isolates	General linear mixed models, a survey to assess antibacterial restriction and antibiogram construction, antibiograms to assess resistance, carbapenems use as days of therapy per 1000 patient days (DOT/1000 PD)
Lima 2011[7]	Pre/post cumulative susceptibility test, DDD/1000 patient days	Retrospective, pre- and post-restriction analysis
Ahmad 2014[8]	Appropriateness of group two carbapenem therapy	Retrospective analysis of all carbapenem use
Yoon 2014[9]	Susceptibility of *Acinetobacter baumannii* to Group two carbapenems	Before-and-after study following implementation of a program of carbapenem-use stewardship
Viale 2015[10]	30-month incidence rates of carbapenem-resistant Enterobacteriaceae (CRE)-positive rectal cultures and bloodstream infections (BSIs)	Quasi-experimental study, Poisson regression
Serrano 2015[11]	Carbapenems cost and DDD/100 OBD	Prospective, descriptive before-after analysis
Tagashira Y 2016[12]	Monthly carbapenem use as days of therapy (DOT) per 1,000 patient days, hospital mortality rates, and average hospitalization duration	Before-after, prospective interventional, once-weekly post-prescription prospective audit
Delgado 2015[13]	Monthly ertapenem use in DOT/1000 adjusted patient days (APD), the rates of carbapenem nonsusceptible *P.aeruginosa*, *Escherichia coli* and *Klebsiella pneumoniae*	Retrospective pre-post implementation
Seah 2017[14]	Intervention acceptance and outcomes, including carbapenem utilization (DDD), length of stay, hospitalization charges, 30-day readmission, and mortality rates	Retrospective analysis of the outcome of the review-and-feedback approach based on IDSA recommendations
Hwang 2018[15]	DOT/1000 patient-days, trends of antimicrobial resistance, in-hospital mortality rate per 1000 patient-days	Interrupted time series analysis
Zhang 2019[16]	Evaluating the rationality of carbapenem use	A point-score system Retrospective
Johnk 2019[17]	Change in carbapenem DOT across 23 hospitals after a stewardship intervention and determine changes in morbidity, mortality, and resistance rates.	Retrospective, multicenter, sequential period analysis
Ruttimann 2004[18]	Comparative DDD of the restricted antibiotics, before and after the implementation of the stewardship program, mortality and rehospitalization rate, length of stay, relapse during hospitalization	Quasi-experimental, before-after study
Sick 2013[19]	Cost analysis and cost-saving after the restrictions on 33 antibiotics	Longitudinal, retrospective cohort
Ansari 2003[20]	Antibiotics use before and after the implementation of an 'Alert Antibiotics' intervention	Drug use and cost analysis by interrupted time series with segmented regression analysis
Gums 1999[21]	The median length of stay after the intervention, time-specific mortality risk, median patient charges for radiology, laboratory, pharmacy, and room, and median hospital costs	Prospective, randomized controlled study
Scheetz 2009[22]	Cost per QALY	Probability-based cost-effectiveness using QALY
Hamblin 2012[23]	Mean LOS, mean annual wage for pharmacists at general medical and surgical hospitals subtracted from the total cost savings	Retrospective cost-saving analysis after PharmD intervention
Lin 2013[24]	Costs, consumption (DDD/1,000 patient-days), the percentage of antimicrobial agents in total drug costs	Retrospective cost-saving after educational intervention
García-Rodríguez 2019[25]	Cost of treatment, inpatient days, and hospital readmission, antibiotic consumption as defined daily doses (DDD) per 100 occupied bed days	Pre- and post-intervention descriptive analysis
Delory 2013[26]	Carbapenems consumption (DDD/1000 patient-days), the median length of stay, and mortality rate	Before-after, vancomycin-controlled interrupted time-series
Mouwen 2020[27]	Duration of IV therapy, length of hospitalization	Historically controlled prospective intervention, educating physicians, handing out pocket-sized cards, and providing switch advice in the electronic patient record
Niwa 2012[28]	Antimicrobial use density, treatment duration, duration of hospital stay, the occurrence of antimicrobial-resistant bacteria, and medical expenses	Prospective, guideline-based, pre-post intervention prescription analysis

Author/Year	Metrics	Method
Chandrasekhar 2019[29]	Parenteral antimicrobial administration, cost of antibiotic therapy, DDD/100 Bed days	Cost minimization analysis of IV to oral conversions, post-intervention audit
Dik 2015[30]	Implementation costs, cost-saving, investment return	Cost-minimization analysis through comparing audited patients with a historic cohort with the same diagnosis-related groups
Slayton 2015[31]	Antimicrobial Use and Resistance (AUR), Clostridium difficile infection (CDI) control	Markov model with a five-year time horizon, Cost-benefit analysis, sensitivity analyses for intervention effectiveness and cost
Bhavnani 2008[32]	Cost as three strata: drug acquisition costs, the first stratum plus preparation, dispensing, administration costs, and the cost of treatment of antibiotic-related adverse events and clinical failures, and the previous two strata plus LOS per diem costs.	Cost-effectiveness analysis
Collins 2019[33]	Procalcitonin (PCT)-guided antibiotic use in ICU for sepsis	Cost-minimization and cost-utility analyses, single-center, retrospective cross-sectional
McKinnell 2018[34]	Drug cost, total treatment cost	Decision-analytic model for cost-effective drug utilization
Okumura 2016[35]	(I) Hospital length of stay/patient-day, (II) cost of defined daily doses (DDD)/patient, (III) resources to provide microbiological and imaging diagnosis of infections, and (IV) human resources workload per day.	Cost-effectiveness using Markov model followed by deterministic one-way sensitivity analysis
Ruiz-Ramos 2017[36]	Consumption of antimicrobials, as well as the incidence of *Clostridium difficile* infections (CDI)	Cost-effectiveness analysis followed by sensitivity analysis
Voermons 2019[37]	Length of hospital stay	Cost-effectiveness analysis, decision algorithm
So 2018[38]	Antimicrobial utilization per month, in defined daily dose (DDD), normalized to 100 patient-days	Retrospective observational time-series study
Gutierrez 2019[39]	Comparative antimicrobial consumption, number of defined daily doses per 100 occupied bed days (DDD/100 OBD)	Consensus by a panel of experts on infectious diseases, microbiology and antimicrobial therapy, through a modified Delphi method
Thabit 2021[40]	DOT/1000 PD, specific antibiotic use (narrow-spectrum β-lactams, non-carbapenem antipseudomonal β-lactams, carbapenems, anti-MRSA agents	Linear regression (β coefficient)
Xiao 2020[41]	Antibiotic procurement and consumption data and antibiotic resistance surveillance data	Descriptive and frequency analysis
Jover-Saenz 2020[42]	Consumption of antimicrobials expressed in DDD per 100 OBDs	Prospective intervention study with historic cohort (before and after)
Mewes 2019[43]	Costs and effects of Procalcitonin-guided care on LOS, costs per patient (treatment costs and productivity losses), costs per antibiotic day avoided	Application of a health economic decision model to compare the costs and effects
Stocker 2020[44]	Absolute antibiotic consumption, DDD/100 OBDs, cost saving	Retrospective, pre-/post-observational comparison
Onorato 2020[45]	Antibiotic consumption, the mean length of stay and the antibiotic expense	Prospective, interventional, interrupted time series analysis
Penalva 2020[46]	Quarterly antibiotic use (prescription and collection by the patient), DDD per 1000 inhabitants per day	Quasi-experimental intervention, interrupted time series analysis
Scott 2019[47]	Treatment costs, intervention costs, the value of statistical life, which was used to estimate the economic value of morbidity and mortality risk reductions	Net present value model to assess social costs and benefits
Vazin 2018[48]	Cost-saving, all-cause in-hospital mortality, the median length of hospital stay	Interventional, prospective study

DOT: Days of therapy; PD: Patient day; QALY: Quality-adjusted life year; LOS: Length of hospital stay; DDD: Defined daily dose; OBD: Occupied bed days; IDSA: Infectious diseases society of America; MRSA: Methicillin-resistant *Staphylococcus aureus*

and antibiotic restriction/preauthorization (12%).[54] It is expected that variation in the cost of implementation depends on the type and scope of the intervention. However, according to a recently published systematic review, the association between the type of ASP implementation and implementation cost is not strong.[54]

In most of the ASPs, the implementation cost is negligible, as the intervention is limited to post-prescribing review and feedback, and existing full-time practitioners handle the process, with no additional cost.[21] However, there are reports of ASP operational costs, as big as 243%, which is attributed to the intervention strategy, i.e., the strategies such as altered therapy guidelines and antibiotic restriction lists of pre-authorized agents do not impose a significant cost, whereas therapy evaluation, review, and/or feedback may increase the operational cost.[54]

A comprehensive cost evaluation of ASP may not ignore the societal costs, which include costs to the insurance company, costs to the patient, and indirect costs due to the loss of productivity.[55] To consider the societal costs, Roberts and colleagues focused primarily on the excess mortality costs due to antimicrobial-resistant infections (ARI). They multiplied the number of deaths attributable to ARI by the lost productivity cost (in 2000 US dollars) for each age group.

For survivors of the ARIs, they considered the attributable length of stay multiplied by the daily cost for lost productivity in the year 2000.[56] Although this work covers one of the main elements of societal costs, some other important elements, such as insurance costs and indirect patient costs were neglected.

Michaelidis and others suggested four methods to estimate the components of the incremental societal cost of antibiotic resistance associated with hospitalization, second-line inpatient antibiotic use, second-line outpatient antibiotic use, and finally antibiotic stewardship.[57] The authors aimed to investigate and estimate poorly understood and hidden downstream societal costs of antibiotic resistance, attributable to ambulatory antibiotic prescribing. In terms of antibiotic stewardship, for instance, their focus is on the physician and pharmacist salary and educational costs. The article provides clues about how to estimate each of those cost components. Meanwhile, depending on the purpose of the study, this article is a good example of how different the components of societal costs can be. For example, when the objective of a study shifts from the cost evaluation of a specific condition to cost-saving derived from a specific intervention, the components of cost analysis may vary remarkably. Hamblin and colleagues addressed 26 elements of cost-saving to analyze the impact of PharmD intervention in the prevention of adverse drug reactions,[23] from prevented adverse drug events and antibiotic consultation to the length of stay.

Surrogate Metrics of Cost

Antibiotics procurement may not provide the most accurate and reliable indicator of the financial impact of ASP, as it is not inclusive enough and can be confounded by many other parameters, such as hospital occupancy rate, price variation over time, or brand. Defined Daily Dose (DDD), length of hospital stay (LOS), or days of therapy (DOT) are some indicators of cost variation in general, and antibiotics use, specifically.

Shifting from general procurement (and expenditure, as an alternative) to Defined Daily Dose (DDD) (usually with 100 or 1000 occupied bed days as the denominator) helps to standardize antibiotic use and subsequently provides a metric for comparing the financial outcome of ASP before and after implementation or from center to center.[57]

DDD is adopted by WHO and defined as the average adult dose recommended for the main indication, as reflected by the Anatomical Therapeutic Chemical (ATC) classification.[58] DDDs per 1000 population per day is interpreted, as the proportion of the population that receives the interested medicine on any given day. DDDs per 100 bed-days (adjusted for occupancy rate) is used more frequently in hospital settings, which provides a measure of inpatients that receive a DDD.[59] For antibiotics that are typically being used in a short period, DDDs per inhabitant per year are preferred. This provides an estimate of the number of days, for which each person is treated with the antibiotic in a year.[60] Patient-day or bed-day is often the denominator for DDD calculations in hospitals. The discharge day would not be counted to avoid the inflation of the denominator by partial days.[59]

Ruttimann's study, for instance, is a quasi-experimental, before-after study that analyzed the financial impact of an antimicrobial stewardship program for a period of four years.[18] The implemented program was mandatory approval for restricted antibiotics (such as ceftriaxone, ceftazidime, piperacillin-tazobactam, imipenem-cilastatin, and vancomycin) as well as a comprehensive educational program. The primary endpoint of this study was a comparative defined daily dose (DDD) of the restricted antibiotics, before and after the implementation of the stewardship program. At the same time, some clinical endpoints of drug therapy, such as mortality and rehospitalization rate, length of stay, relapse during hospitalization, and so on were investigated to ensure the cost-saving may not aggravate the clinical outcomes. Where the focus of the ASP is limited to a particular class of antibiotics, any cost analysis of such an ASP must consider the potential for the clinicians to switch from the given antibiotics to an alternative antibiotic, to bypass the audit or prescription limitations. Therefore, the potential alternative antibiotics should be identified and brought into analysis to ensure that the overall antibiotic consumption has been evaluated properly.[25]

Some researchers suggested a potential

change in the consumption of the third-generation cephalosporins, piperacillin-tazobactam, and quinolones, when ASP targeted carbapenems.[26]

More recently, a selected committee of Spanish Societies of Hospital Pharmacy and Infectious Diseases and Clinical Microbiology published the consensus on hospitals' antibiotic use indicators.[39] It is an advisable list of particular antibiotic classes as priority-based target antibiotics in ASPs.

Length of hospital stay (LOS) is one of the major endpoints of all ASPs. This is because LOS is on one hand a clinical indicator of ASP success, and on the other hand is an important parameter, through which the cost-saving can be evaluated. The financial aspect of LOS is tightly related to the evaluation of the cost of the hospital per day. An example of a hospital cost analysis is the analysis of University of Malaya Medical Centre (UMMC) services, published in 2012. It reported the average length of stay (ALOS) for the medical and surgical wards as 6.7 days (SD 8.886) and 5.6 days (SD 9.005), respectively. According to this report, the cost per diem for medical and surgical wards was 641.15 Malaysian Ringgits (~USD 153), and 1,085.48 Malaysian Ringgits (~USD 260), respectively.[61] These rates can be considered as the basis of cost calculations at any time, where the medical services inflation rates are considered.

A comprehensive example of inpatient cost evaluation is the TrendWatch Chartbook 2016,[62] that provides detailed components of inpatient cost evaluation. A 2019-adjusted average inpatient hospital expense per day is also accessible online.[61]

Nevertheless, referring to LOS as an indicator of cost analysis faces complexities, as some authors have pointed out. Firstly, the cost of a single additional day of hospital stay is much different from critical care to non-critical care inpatients. Secondly, the cost of an additional day of hospital stay reduces by time, i.e., the cost of the 20th day of hospital stay can be as low as 20% of the second day of admission.[63] Some researchers argued that providing a cost analysis based on the observed difference in LOS may not be feasible due to the inevitable differences among the antibiotics consumers who participate in different studies, as well as the difference between the severity of the infections among the treatment and control groups in the implemented ASP.[64] However, the Kaplan-Meier plot in a Japanese ASP report confirms a drop in LOS after the implementation of ASP on parenteral antibiotics.[28] This statistically significant one-day reduction in LOS was reported to cause US$1.95 million, and US$3.92 million to be saved in the two periods of ASP. The authors calculated the hospital charges with the inclusion of 40% diagnosis–procedure combination (DPC) of the mean unit charge for the hospital stay and the number of patients receiving antibiotic injections. LOS, as a metric of ASP, has been used in multiple studies with various methodologies.[32, 35, 37, 43, 45]

Days of therapy (DOT) have been used by some researchers as a metric of ASP. Monthly carbapenems use as DOT per 1000 patient days is reported with a significant reduction of carbapenems use by half.[12] The segmented regression analysis of an interrupted time series confirmed the finding. Some other typical ASP studies with DOT as one of the study metrics have been published in recent years.[13, 15, 64]

Voermans and others is a comprehensive ASP cost-effective analysis that integrated LOS for both ICU and general wards, and DOT to come up with a procalcitonin-guided decision algorithm.[37]

It is important to identify the trends and turning points of variation in cost or other metrics, when an ASP is being analyzed over time. Interrupted time series analysis and longitudinal regression are ideal statistical approaches to address this matter.[45, 46]

The variables that potentially confound the analysis should be addressed. First, the severity of the disease should be adjusted to ensure that the compared patient groups (before/after ASP implementation or ASP interference adherent/nonadherent cases) are reasonably analogous. For this purpose, a generic instrument of illness severity assessment can be deployed for all included patients.[65] The second potential confounder is the patients' ages that warrant the variable adjustment.

In general, LOS remains a superior metric of clinical and cost-saving analysis of ASP, compared to the days of therapy (DOT) or DDD, which are disease-specific.[66]

Methods of ASP Financial Evaluation

The financial methods of ASP evaluation are the same as the general healthcare economics evaluation methods. Many of these methods can technically be categorized under the cost-effectiveness umbrella. However, the specific characteristics of the interested end-points in cost-benefit, cost-minimization, or cost-utility analyses suggest that the discussion is focused on each technique.

Cost-Effectiveness

Despite all available pieces of evidence of beneficial outcomes of ASP and technical improvements, the thorough assessment of cost remains a complicated and unsolved problem.[67]

A multicentered randomized trial that evaluated the cost-effectiveness of oral gemifloxacin versus intravenous ceftriaxone followed by oral cefuroxime with/without a macrolide for the treatment of hospitalized patients with community-acquired pneumonia, categorized the cost as three strata. The first stratum was drug acquisition costs, the second stratum included the first stratum plus preparation, dispensing, administration costs, and the cost of treatment of antibiotic-related adverse events and clinical failures. The third stratum was the previous two strata plus LOS per diem costs. The effectiveness was evaluated based on the clinical success, failure, or intermediate response of the patients.[32]

Collins and colleagues reported the cost-effectiveness of procalcitonin (PCT)-guided antibiotic use, where the effectiveness is stated in terms of quality-adjusted life years (QALYs).[33] The researchers classified the cost variables as antibiotic therapy, PCT assay, and attributable costs (septicemia, nephrotoxicity, *Clostridium difficile* infection). LOS was classified under 'duration variables' along with other parameters.

Designing a decision tree, usually the Markov model, is very common in cost-effectiveness studies. The key question is sometimes a comparison of two specific drugs[34] and sometimes two antimicrobial programs.[35] The decision tree enhances revealing the outcomes variety, as well as potential confounders. However, the important concern that remains in cost-effectiveness analyses of ASPs is the complexity of anticipation of saved cost due to the prevention of future infections.[68]

Cost-Benefit

Slayton and colleagues attempted to provide a cost-benefit analysis of multifaceted infection control and antimicrobial stewardship program from the federal payer perspective.[31] This study focused on the epidemiologic and economic value of the implementation of a multifaceted *Clostridium difficile* infection (CDI) control program at US acute care hospitals, using TreeAge Pro Suite software to construct a Markov model. The basis of calculation of effectiveness was a United Kingdom report of a 59% reduction in the number of CDI cases after the implementation of multifaceted infection control and antimicrobial stewardship program. They used the Bureau of Labour Statistics to take the wage of personnel into account. Other cost elements, such as laboratory supplies and contracts, extramural funding, and development and support of NHSN modules were adopted from CDC annual program budgets from the Office of Chief Financial Officer. Based on the model, the cost-beneficial analysis showed that $2.5 billion (95% credible interval: $1.2 billion to $4.0 billion) could be saved over a five-year horizon.

Cost-Minimization

The objectives of cost-minimization analysis are very close to cost-saving analyses. The cost-minimization analysis of the outcome of an ASP can be a suitable approach for investigating the short-term impact of ASP. The drawback of the cost-minimization ASP analysis is stated to not address the long-term impacts of ASP, especially the impact of the ASP on the emergence of microbial resistance.[68]

The analysis of the financial impact of conversion of parenteral to oral antibiotic therapy is a suitable area for application of the cost-minimization approach in ASP due to the involvement of a limited number of variables, as well as the short duration to observe and evaluate the outcomes. Controlled interventional studies are of course the best type of designs for such an analysis.[29]

A framework of the cost-minimization model to measure the direct costs and benefits of ASP is suggested.[30] This model is based on a day two case-audit by a multi-disciplinary ASP team. The one-year financial impact of the post-audit intervention in 114 cases was compared with that of a 30-month control cohort. The subgroup analysis based on the Diagnosis Related Group (DRG) codes was performed by the researchers to address modifying disease-related factors. A pre-existing estimated cost of €716 per patient per day was deployed in this study. The overhead costs (including building costs, maintenance, equipment, personnel costs for daily care) were included in these estimations, whereas procedures were excluded, since a reduction in LOS did not influence the number of procedures substantially.

Conclusion

The objectives of antimicrobial stewardship programs are generally classified as either clinical or financial objectives. Although the financial objectives are not the primary objectives of the ASPs from the viewpoint of clinicians, in the absence of a positive perspective of financial output, it would be difficult to acquire the approval of the managers for conducting ASPs. A profound understanding of relevant methods and metrics, in accordance with the particular healthcare center, allows the clinicians to develop the ASP protocol wisely with an augmented likelihood of positive financial output and subsequently, stepping forward for a wider scope of ASP implementation.

Authors' Contribution

F.K: Contributed to study design, data acquisition, and drafting the work. The author approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest

Fazlollah Keshavarzi, as the Editorial Board Member, was not involved in any stage of handling this manuscript. A team of independent experts were formed by the Editorial Board to review the editor's article without his knowledge.

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