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ORIGINAL ARTICLE

The value of specialist care—infectious disease specialist referrals—why and for whom? A retrospective cohort study in a French tertiary hospital

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Abstract This study evaluated the impact of infectious disease (ID) specialist referrals on outcomes in a tertiary hospital in France. This study tackled methodological constraints (selection bias, endogeneity) using instrumental variables (IV) methods in order to obtain a quasi-experimental design. In addition, we investigated whether certain characteristics of patients have a bearing on the impact of the intervention. We used the payments database and ID department files to obtain data for adults admitted with an ID diagnosis in the North Hospital, Marseille from 2012 to 2014. Comparable cohorts were obtained using coarsened exact matching and analysed using IV models. Mortality, readmissions, cost (payer perspective) and length of stay (LoS) were analysed. We recorded 15,393 (85.97%) stays, of which 2,159 (14.03%) benefited from IDP consultations. The intervention was seen to significantly lower the risk of inpatient mortality (marginal effect (M.E) = –19.06%) and cost of stay (average treatment effect (ATE) = –€5,573.39). The intervention group was seen to have a longer LoS (ATE = +4.95 days). The intervention conferred a higher reduction in mortality and cost for stays that experienced ICU care (mortality: odds ratio (OR) =0.09, M.E cost = –8,328.84 €) or had a higher severity of illness (mortality: OR=0.35, M.E cost = –1,331.92 €) and for patients aged between 50 and 65 years (mortality: OR=0.28, M.E cost = -874.78 €). This study shows that ID referrals are associated with lower risk of inpatient mortality and cost of stay, especially when targeted to certain subgroups.

Background

When seeking avenues to cut costs, policy makers are prone to question the legitimacy of specialist care, as it has been often cited as a major contributor to excessive treatment costs without offering significant added value [1]. In this group, certain specialists, e.g., infectious disease (ID) specialists and geriatricians,

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are seen as groups that consume more resources [1, 2]. This has led to increased scrutiny by policy makers, who are keen on evaluating outcomes to ascertain the value of specialist care. It has therefore become essential for specialists to demonstrate the value of their contributions to stakeholders [1–4].

Infectious disease physicians (IDPs) are often requested for consultation from other specialty departments with an aim to optimize care for patients with multiple morbidities [4]. IDPs also play a significant role in administration, research, hospital infection control, antimicrobial stewardship and medical education. It is therefore important to point out that viewing IDPs as mere consulting physicians for antibiotic therapy management obfuscates their contributions to health care systems [3, 5, 6]. The nature of advice offered by IDPs ranges from diagnostic to therapeutic, and has often been found to be resource-sparing, and often more so when ID referrals are requested early during hospitalization [7, 8].

Multiple studies have analysed the effect of IDP consultations on clinical outcomes in specific morbidities. Studies have shown that IDP consultations significantly lower mortality in *Staphylococcus aureus* bacteraemia (SAB), urinary tract infections, *Staphylococcus aureus* sub-acute bacterial endocarditis and HIV infection [6, 9, 10]. There is also evidence showing that ID consultations offer significant benefits to certain departments in hospitals, e.g., oncology, intensive care and solid organ transplant units [11–13]. This has prompted a push for dedicated IDPs in hospitals to facilitate routine consultation (phone/bedside) or mandatory consultation for specific morbidities [3, 7, 11].

Research has produced mixed results on the effect of ID specialist consultations on costs and duration of hospitalization [1, 4]. It is difficult to circumvent the many methodological constraints (selection bias, endogeneity) that limit the generalizability of the results of previous research on the value of ID consultations [14, 15]. One of the major reasons for the paucity of evidence is the difficulty faced in designing suitable trials, e.g., where the referral would be introduced non-selectively, as in a randomized controlled trial. This study seeks to tackle these methodological constraints and evaluate the impact of ID referrals on clinical and efficacy outcomes in a tertiary hospital in France, where all the ID referrals are formally recorded and reformulated as "exogenous," thanks to the use of instrumental variable (IV) regression methods. This creates the design of a quasi-experimental study [16, 17]. In addition, we attempted to identify if certain characteristics of patients or of their hospital stay had a bearing on the impact of the intervention; this second point is a novelty for the literature.

Methods

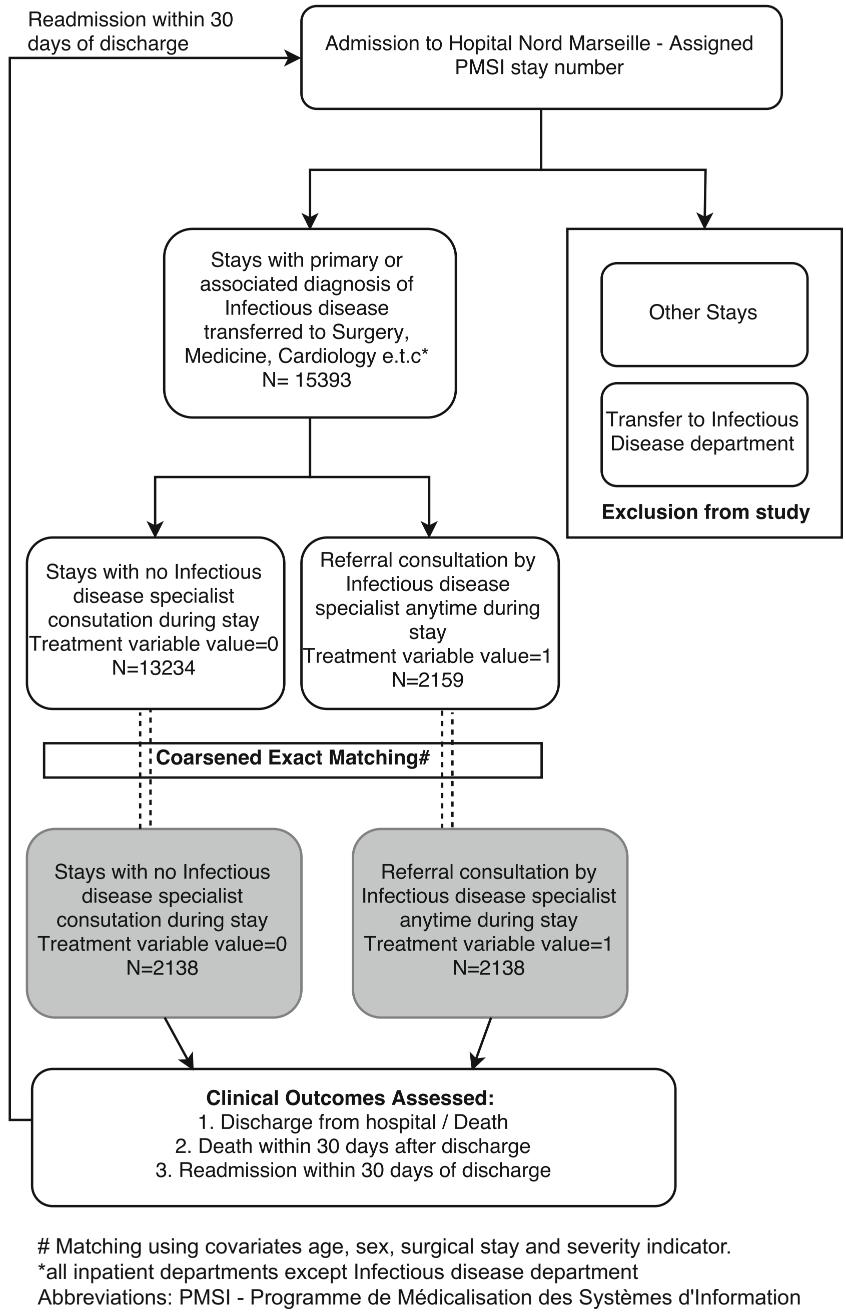
The study took place in the North Hospital (Hôpital Nord) in Marseille, southern France. The hospital is a tertiary care facility, which serves as a reference centre for many medical and surgical specialties. The hospital has a dedicated department for infectious diseases—the "Maladies Infectieuses et Tropicales (MIT)". The MIT is composed of six residents, one fellow, one assistant professor and one professor. The ID department provides referral services to other departments in the hospital on request and also has its own dedicated inpatient section. In order to ensure quality of referral services it is mandatory that the residents discuss with the assistant professor or the professor before offering final referral advice. The department is also responsible for microbiology and parasitology laboratories, hospital hygiene, a travel vaccination centre and rabies treatment centre. It also serves as a centre for disease surveillance and biosecurity.

The study population is comprised of all adult patients who were admitted to the North Hospital, Marseille with an infectious disease diagnosis (primary or associated) in the period from the January 1, 2012 to December 31, 2014. Diagnostic codes utilized are listed in supplementary data. All stays transferred to the ID department were excluded from the study. Data from two sources were combined to obtain the final dataset. The first source is an extract from the Programme de Médicalisation des Systèmes d'Information (PMSI) database and the second source is the ID department consultation tally sheets. The PMSI is a budgeting tool for the Diagnosis Related Group (DRG) payment system. The DRG code (code GHM, for "Groupes Homogènes de Malades") contains information regarding the type of stay (medical, surgical, etc.) and level of severity of illness. The severity-of-illness indicator (niveau de sévérite) is an ordinal variable that takes integer values between 1 and 4 depending on the duration of stay, age, DRG and associated morbidities of the stay with '4' indicating the highest level of severity of illness and '1' the lowest. The PMSI data was matched with the tally sheet coding based on unique stay numbers (PMSI number). Each unique admission was considered as the unit of analysis.

Key variables

The treatment variable is a binary variable that takes the value '1' if a stay benefited from at least one ID specialist consultation and '0' if not (Fig. 1). Five outcome indicators were selected for the study. This included three clinical outcomes: inpatient mortality, readmission within 30 days of discharge and mortality within 30 days after discharge, and two cost and efficiency indicators from a payer perspective: length of stay and total cost of stay. Costs of stay were denominated in euros and are calculated for each DRG stay in the PMSI extract. The costs designated are not actual costs incurred, but are assigned based on the DRG of admissions and certain characteristics of

Fig. 1 Study flow diagram



the admission, for example, length of stay. Matching and explanatory variables utilized in the regression models are listed in Table 1.

Statistical analysis

Descriptive analyses were done for the explanatory variables, outcomes across the entire study population and by treated (received ID consultation) and untreated groups (no ID consultation). Comparison across groups was done using t-tests for continuous variables and chi-square tests for categorical variables. We used Stata 13 for matching and analysis [18].

Dealing with unbalanced samples of case/control subjects and with possible "endogeneity" in the intervention

Matching

Randomized trials are the best methods to estimate the effects of clinical interventions; however, issues of feasibility, cost, time and ethics deprived us of the option in this situation [19]. Using observational data is not free from hurdles. The possibility exists that the estimated treatment effect would be biased due to confounding caused by covariates that are unequally distributed in the treatment and

Table 1 Matching and regression variables

Coarsened exact matching (CEM) variables	Regression variables
Patient age	Patient age
Patient gender	Patient gender
Type of stay — surgical or not	Type of stay — surgical or not
Severity of illness indicator	Primary diagnosis infectious disease or not
	Intensive care unit utilization during stay or not
	Severity of illness indicator[a]
	Nosocomial infection during stay or not
Outcome variables	Subgroup analysis variables
Inpatient mortality	Patient age groups
Mortality within 30 days after discharge	Patient gender
Readmission within 30 days after discharge	Severity of illness indicator (re-categorized)
Length of stay	Intensive care unit utilization
Total cost of stay	Major diagnostic category (top 3 frequent post CEM)

CEM coarsened exact matching

[a] Ordinal variable taking values 1–4; 1 is lowest severity, 4 is highest severity

control groups. The objective is to control for confounding, and one solution proposed is the use of matching methods. The objective of matching is to pair observations so as to obtain comparable groups adjusted on possible confounders [20, 21]. Two of the most commonly used matching methods are propensity score matching (PSM) and coarsened exact matching (CEM) [22]. CEM has been shown to be an effective alternative to PSM. CEM involves stratification of the sample based on select characteristics (e.g. age, sex, etc.) and matching within the strata based on likelihood of receiving the intervention. Compared to PSM, CEM provides estimates of treatment effects with the lowest possible bias and variance for similar sample sizes [22, 23]. We decided to use CEM to match patient groups on the covariates age, sex, surgical stay and severity indicator, as these could be potential confounders.

Matching and analysis

Regression models were employed to study the effect of ID consultations on the outcome indicators post CEM. The three clinical outcomes were modelled using logistic regression. Length of stay was modelled using negative binomial regression (count data). A generalized linear model with log link and gamma distribution was utilized for modelling total cost of stay. In addition, length of stay was also considered as an explanatory variable for total costs.

Endogeneity and the instrumental variable method

The probability of receiving the ID consultation cannot be assumed to depend only on the set of observed covariates. The budgetary nature of PMSI data limits the ability to analyse patient characteristics in detail. The unobserved patient characteristics might have a bearing on the probability of receiving the intervention, and therefore also impact outcomes. As a result of this, an "endogenous" relationship was introduced between intervention and outcomes. In order to address this endogeneity issue, instrumental variable (IV) methods were utilized. These techniques are popularly employed to treat similar confounding in economics and healthcare research. For this purpose, it is essential to identify an appropriate instrument, a variable that would be correlated to the intervention but not to the outcomes. The IV estimation involves the specification of two sets of structural equations, of which the intervention assignment constitutes the first. This first step estimates the intervention with the confounders and the instrument (s) acting as predictors. The subsequent step would then model the outcome [24].

The IV in this study was the overall probability of being referred for an ID consultation from a particular medical unit (calculated for 3 years (2012–2014)) and is intended to be a proxy for the clinical practice behaviour of the referring department. This was guided by the fact that the head of the department is in charge of training doctors and the formulation of referral guidelines. Similar IVs that measure physician preferences have been utilized in previous health economics studies [24, 25]. The probability of receiving an ID consultation was modelled using the instrument and other covariates. The first stage F-statistic for the IV was 891.81, implying that the chosen instrument is "strong". The Anderson canonical correlations test also indicated that the IV model was well identified and relevant ($p < 0.001$). A biprobit specification was utilized for the dichotomous outcomes, and a 2SLS model comprised of a probit first stage was used for the count outcomes.

Sub-group analysis

In the second part of the study, the analysis focused on select subsamples in order to investigate whether the impact of the intervention differed between groups. The criteria for grouping were sex, age, severity of illness, type of stay (surgical or not) and major diagnostic category (MDC). The age groups chosen were below 50 years, between 50 and 65 years and greater than or equal to 65 years. The use of the intensive care unit (ICU) during the hospital stay was used as a grouping criterion, in addition to the severity indicator. Severity was regrouped into low (level 1 or 2) and high (level 3 or 4) severity. The top three MDCs (respiratory disease, circulatory system disorders & musculoskeletal diseases and injury) in the matched sample were selected for group-wise analysis (Table 2). In order to compare coefficients between sub-groups, we utilized statistical methods analogous to the Chow test [26]. The estimation is done by specifying models for the entire sample and sub-samples, and testing if the coefficient of the independent variable differs across the models. Hypothesis testing was done using the likelihood ratio test (for dichotomous outcomes) and the seemingly unrelated estimation test (for continuous outcomes) [27].

Results

Descriptive statistics prior to matching

During the study period there were a total of 15,393 stays that fit the study criteria, of which 2,159 stays benefited from specialist ID physician consultations. Descriptive statistics of patient characteristics and outcomes in the entire study population and according to the treatment group ("ID consultations" versus "no ID consultations") are presented in the Supplementary data Tables 1 and 2, respectively.

Compared to the non-ID group, the group that received ID consultations was more likely to be male (61 %). The intervention group (ID group) had a greater proportion of stays with severity levels equal to or greater than 3, a longer mean LoS, lower mortality rate and higher mean costs than the group that received no referrals. The ID group was also more likely to be surgical stays and less likely to have had ID as a primary diagnosis. The ID group had a higher proportion of stays that required intensive care or resuscitation.

Descriptive statistics post coarsened exact matching

CEM was done using the K-to-K matching mode, so that weights need not be considered and matched treatment and control groups have the same number of observations. Post CEM, the sample comprised 2,138 stays each in ID and non-ID groups. The CEM resulted in groups with similar demographic characteristics (Supplementary data Table 3). Significant differences in outcome indicators—in patient mortality, length of stay and total hospitalization cost—remained after matching. No significant difference was observed for mortality within 30 days post discharge and readmissions (Table 3).

Results post risk adjustment

ID consultation events were associated with a significantly lower risk of inpatient mortality (OR = 0.38). No significant effect was observed on death within 30 days after discharge and readmission within 30 days post discharge. ID

Table 2 Major diagnostic categories in study groups prior to matching

Major diagnostic category	Non ID group	Percent of total stays	ID group	Percent of total stays
Disorders of the circulatory system	1,361	10.28	358	16.58
Disorders and injuries of the musculoskeletal system and connective tissue	539	4.07	325	15.05
Disorders of the respiratory system	4,116	31.1	242	11.21
Skin, subcutaneous tissue and breast	1,043	7.88	225	10.42
Disorders of the digestive tract	973	7.35	182	8.43
Nervous system	650	4.91	176	8.15
Trauma, allergies and poisoning	193	1.46	146	6.76
Infectious and parasitic diseases	463	3.5	93	4.31
Renal and urinary tract	1,229	9.29	73	3.38
Disorders of the ears, nose, throat, mouth and teeth	253	1.91	58	2.69
Disorders of the hepatobiliary system and pancreas	362	2.74	46	2.13
Disorders of the male reproductive system	306	2.31	21	0.97
Other	1,746	13.19	214	9.91
Total stays	13,234		2,159	

ID infectious disease

Table 3 Unadjusted outcomes post CEM ($N = 4,276$)

Variable	ID consultation, N = 2138		No ID consultation, N = 2138		P value
	Number	Percent	Number	Percent	
Mortality rate during hospitalization	29	1.36 %	74	3.46 %	<0.01
Readmission within 30 days after discharge	216	10.1 %	199	9.31 %	0.38
Mortality within 30 days after discharge	17	0.8 %	22	1.03 %	0.42
Cost (in €) mean (SD), median [IQR]	10,759 (11,145.38), 7,612 [434–168,728]	NA	12,289.89 (17,468.25), 6,325.24 [479.42–211,887.1]	NA	<0.01
Length of stay (MLoS) in days, mean (SD), median [IQR]	20.6 (20.57), 15 [1–292]	NA	15.88 (17.76), 10 [1–189]	NA	<0.01

CEM coarsened exact matching, *IQR* interquartile range, *MLoS* mean length of stay, *NA* not applicable, *SD* standard deviation

consultations were seen to have a significant effect on lowering the total cost of stay (marginal effects (M.E)) = −€416.25), but were associated with a higher length of stay (incidence rate ratio (IRR) = +36.16 %). The IV analysis reconfirmed the effects of intervention on augmenting length of stay (average treatment effect (ATE) = +4.95 days) and reducing total cost of stay (ATE = −€5,573.39). The intervention was also seen to have the effect of lowering in-patient mortality (M.E. = −19.06 %). The results of the multivariate regression and IV models are presented in Table 4.

Sub-group analysis results

Admissions in the age group ≥50 and <65 years benefited more from the ID referral compared to younger and older admissions (≥65 years) in terms of mortality reduction and cost of stay. Admissions that involved ICU care were seen to benefit more from the intervention in terms of reduction in mortality and cost of stay. The ID referral was seen to have a greater cost-lowering effect for stays assigned severity level ≥3. Major diagnostic category: circulatory system disorders were seen to have had more benefit from the ID referral than other MDCs in terms of mortality reduction. The intervention was seen to have different but augmenting effects on length of stay in all subsample models, except with respect to sex (Table 5).

The intervention was not associated with any significant impact on readmission and death 30 days post-discharge, both in the full model and all subgroups analysed (Supplementary data Table 4). No sub-group differences were observed for the impact of the ID consultation on inpatient mortality when considering sex, surgical stay and severity indicator as group criteria. The ID referral was not seen to have effects on cost and length of stay for the MDCs analysed.

Discussion

Aging patient populations with complex diagnoses result in physicians having to request IDP consultations in order to tap their specialist knowledge [4]. Although this may seem to be the best solution, there is a paucity of evidence to suggest that this option provides a valuable return. One of the major reasons for this lack of evidence is the difficulty faced in designing and financing suitable clinical trials. If the intervention of the IDP is systematically reserved to severely ill patients, the statistical evidence on the IDP intervention, compared to no intervention, will be strongly biased in favour of a mortality issue. At the least, the comparison samples

Table 4 Risk adjusted post match outcomes ($N = 4276$)

Outcome variable	Post CEM	P value	OR/% Δ (95 % CI)/marginal effect	IV model results	OR/% Δ (95 % CI)/marginal effect
Inpatient mortality	−0.97	<0.01	0.38 (0.25–0.59)	−1.54**	−19.06 % (−26.27 to −11.84 %)
Readmission within 30 days	0.091	0.38	1.10 (0.89–1.34)	−0.18	−3.2 % (−7.7 to +1.34 %)
Death 30 days post discharge	−0.23	0.49	0.80 (0.42–1.51)	+0.09	0.2 % (−1.16 to + 1.6 %)
Length of stay	0.31	<0.01	+36.16 % (30.76–41.77 %)	+4.95**	2.67–7.24 days
Total cost of stay*	−0.04	<0.01	–416.25 € (−712.85 to −1,119.66)	−5,573.39 €**	−6,769.76 € to −4,377.02 €

% Δ percent difference, *CEM* coarsened exact matching, *CI* confidence interval, *IV* instrumental variable, *OR* odds ratio
*$p < 0.05$, **$p < 0.01$

Table 5 Value of coefficient of independent variable—full model and subgroups

Variable	Inpatient mortality (CI) (OR)	Cost of stay (CI) (marginal effects)	Length of stay (CI) (IRR)
Full model	−0.97	−0.035**	0.31**
	(−1.41 to −0.53)	(−0.06 to −0.01)	(0.27–0.35)
	(0.38)**	(−416.25 €)	(+36 %)
Female	−0.99	−0.028	0.32**
	(−1.77 to −0.21)	(−0.07–0.01)	(0.25–0.38)
	(0.37)*	(−321.34 €)	(+37.1 %)
Male	−0.96	−0.04*	0.30**
	(−1.50 to −0.42)	(−0.07 to −0.01)	(0.25–0.36)
	(0.38)**	(−502.93 €)	(+35.58 %)
LR test/suest p value	0.053	0.62	0.97
<50 years	−1.85	−0.047	0.36**
	(−4.02 to 0.32)	(−0.10 to −0.003)	(0.27–0.44)
	(0.19)	(−565.66 €)	(+42.84 %)
50-65 years	−1.29*	−0.057*	0.42**
	(−2.3 to −0.28)	(−0.11 to −0.004)	(0.34–0.50)
	(0.28)	(−874.78 €)	(+52 %)
≥65 years	−0.67*	0.003	0.26**
	(−1.19 to −0.16)	(−0.03 to 0.04)	(0.21–0.32)
	(0.51)	(+32.56 €)	29.77 %
LR test/suest p value	<0.01	<0.001	<0.01
Low severity	−0.39	.006	0.42**
	(−1.58 to 0.80)	(−0.05 to 0.06)	(0.34–0.51)
	(0.68)	(26.39 €)	(+52 %)
High severity	−1.04	−0.086**	0.28**
	(−1.52 to −0.56)	(−0.12 to −0.05)	(0.23–0.33)
	(0.35)**	(−1,331.92 €)	(+32 %)
LR test/suest p value	0.13	<0.01	<0.01
ICU	−2.44	−0.33**	0.18 **
	(−3.65 to −1.23)	(−0.38 to −0.27)	(0.10–0.26)
	(0.09)**	(−8,328.84 €)	(+20 %)
Non-ICU	−0.32	0.097**	0.41**
	(−0.83 to 0.19)	(0.07 to 0.12)	(0.36–0.45)
	(0.73)	(+698.15 €)	(+50 %)
LR test/suest p value	<0.01	<0.001	<0.001
Respiratory disease	−0.24	−0.002	0.30**
	(−1.06 to 0.59)	(−0.06 to 0.05)	(0.20–0.40)
	(0.79)	(−21.32 €)	(+35 %)
Circulatory system disorders	−1.58**	−0.036	0.18**
	(−2.3 to −0.52)	(−0.10 to 0.027)	(0.072–0.29)
	(0.21)	(−413.83 €)	(+19.69 %)
Musculoskeletal diseases and injury	−0.81	−0.024	0.30**
	(−2.83 to 1.22)	(−0.09 to 0.04)	(0.16–0.44)
	(0.45)	(−259.43 €)	(+35 %)
MDC others	−1.06	−0.03	0.37**
	(−1.77 to −0.35)	(−0.07 to 0.003)	(0.32–0.42)
	(0.35)**	(−376.45 €)	(+44.84 %)
LR test/suest p value	<0.01	0.9	<0.01
Surgical stay	−1.42	0.08**	0.43**

Table 5 (continued)

Variable	Inpatient mortality (CI) (OR)	Cost of stay (CI) (marginal effects)	Length of stay (CI) (IRR)
	(−2.26 to −0.58)	(0.05 to 0.12)	(0.37–0.49)
	(0.24)**	(1,472.46 €)	(+53.33 %)
Non-surgical stay	−0.76	−0.13**	0.20**
	(−1.29 to −0.23)	(−0.16 to −0.10)	(0.15–0.26)
	(0.47)**	(−889.5 €)	(+22.7 %)
LR test/suest p value	0.13	<0.001	<0.01

CI confidence interval, *ICU* intensive care unit, *IRR* incidence rate ratio, *LR* likelihood ratio, *OR* odds ratio, *MDC* major diagnostic category, *suest* seemingly unrelated estimation

*$p < 0.05$, **$p < 0.01$

must be balanced on observable characteristics. A recent study by Schmitt et al., made on balanced samples, demonstrated the beneficial effect of early ID consultations with regards to patient outcomes and cost of care in a US hospital setting [4]. Previous studies in France have produced ambiguous results or failed to provide strong evidence of clinical benefits for ID specialist consultations, owing to methodological constraints [28, 29]. Our study was based on the necessity of reinforcing methods for the production of evidence, using for this a statistical model in which an attempt was made to control for observed and unobserved confounders as much as possible [16, 17]. Previous studies have pointed to the fact that mandatory inpatient specialty care may actually benefit all stakeholders [4, 6, 7]. There also exists the possibility of having IDPs on deputation to certain specialties in order to obtain better outcomes [7, 11]. ID specialist intervention is seen to have a positive impact on patient outcomes in specific morbidities like SAB [9, 10]. Patients in specific departments, e.g., intensive care and solid organ transplant units, were shown to obtain positive benefits from ID specialist consultations [11, 13].

In line with previous studies, our results show a significant association between ID specialist consultation and lowering mortality and costs. By utilizing more robust econometric methods, this study makes a strong case for the value that inpatient ID specialty care offers to healthcare, both in terms of clinical outcomes and cost of care. Even though the study data is from a single hospital, the study does not restrict analysis to a single diagnosis, as is the case in many previous studies. In contrast with results observed in Schmitt et al., no significant effect was observed on readmissions and/or death within 30 days after discharge. In addition, we observed that ID consultations are significantly associated with a higher length of stay. This augmentation effect of the intervention on length of stay is possibly explained by the necessity for completion of a specific course of therapy (or diagnostics) recommended by the IDP. The cost reduction attributed to the intervention, in spite of an increase in length of stay, could be explained by complications or interventions avoided or ICU care avoided possibly due to expert advice offered by the ID physician.

The impact of the intervention is seen to be significantly different when considering certain subgroups in the study population. Positive impacts on survival and cost of stay were particularly strong in the following groups: stays with a higher degree of disease severity, ICU stays, stays with a diagnosis of cardiac/circulatory system disease and stays aged between 50 and 65 years. The difference in mortality risk attributable to different morbidities and the clinical skill/expertise of physicians in other specialties dealing with ID cases are possible explanations for this finding.

Study limitations

The fact that PMSI data is primarily for budgeting is one of the major limitations that did not permit us to look at morbidity patterns and the exact severity of illness. We were unable to investigate the impact of the intervention unit-wise, because many stays utilized multiple units during hospitalization. The fact that the study is limited to one institution may also be a limitation, as varied healthcare settings and practice behaviours are not accounted for. There also exists the challenge of identifying the level of adherence to IDP treatment recommendations. Also, we did not investigate the issue of the timing of the intervention, because an appropriate cut-off to categorize "early" or "late" intervention could not be identified.

Future investigations

Expanding the study utilizing national datasets or data from several hospitals could be a possible next step. A differentiation on the basis of bedside compared to phone consultations might be interesting to study. To avoid methodological limitations, a prospective randomized intervention could be initiated, but would pose now, with the beneficial outcome on mortality reported in this study, several ethical questions (unless the randomization is limited to the form of the intervention). Extending a similar analysis to specific hospital departments or even to outpatient care may help identify ways to allocate specialist care resources in order to obtain the best value for patients and other stakeholders.

In the current scenario where healthcare budgets are stressed and allocations are decided based on the value offered by interventions, our study results will be of interest for third-party payers, IDP unions such as the Union of European Medical Specialists and to health systems researchers. Similar methodologies could be utilized to investigate the role and value of varied specialties in multiple health scenarios and could aid in optimal allocation of resources.

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Compliance with ethical standards

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Conflicts of interest Manoj Sasikumar, Sylvie Boyer, Anne Remacle-Bonnet and Bruno Ventelou have no competing interests. Philippe Brouqui has a related patent FR2997779 pending. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

Ethical considerations Informed consent and ethics board approval was not required due to the observational nature of this study and the use of anonymized data.

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