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A multi-level strategy for a long lasting reduction in unnecessary laboratory testing: A multicenter before and after study in a teaching hospital network

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Summary

Background: Reducing unnecessary laboratory blood testing in the hospital setting represents a challenge to improve the adequacy of healthcare and a tricky task for teaching hospitals. Our hospital network actively participates in the Choosing Wisely Campaign and is engaged in avoiding unnecessary low value interventions and investigations. We aimed to study whether a multi-level approach combining educational and web-system based interventions, could be effective in reducing laboratory testing and related costs.

Methods: Multicenter, proof of concept, prospective, observational, before and after study, in a network of public hospitals in Switzerland. All patients admitted between 1 January 2015 and 31 December 2017 were analyzed. A multi-level strategy based on online continuous monitor benchmarking and educational support was applied in the internal medicine services. The primary outcome was a significant reduction in the number of laboratory tests per patient and per day during the hospital stay. Secondary outcomes were reduction in the blood sample volume taken per patient and per day in laboratory costs.

Results: Over the 36 months of the study, 33 309 admissions were analyzed. A significant reduction of laboratory tests per patient and per day of hospitalisation was found:–11%, *P*-value<0.001; –6%, *P*-value <0.001. The mean monthly blood volume, per patient and per day of hospital stay and laboratory costs per patient was also significantly reduced: –7%, *P*-value<0.05; –3%, *P*-value<0.01, and –17%, *P*-value<0.01, respectively.

Conclusions: The obtained reduction in the number of laboratory tests, blood volume withdrawn and related costs, support the idea that an open web-based system, involving all health care providers, coupled with educational interventions, can be helpful in generating awareness of prescriber habits and to catalyze changes in their behaviour. The peer pressure related to the unmasked benchmarking process did probably play a determinant role.

#Yannick Erard and Rosaria Del Giorno joint first authorship.

1 | BACKGROUND

Avoiding inappropriate laboratory blood testing in hospitalised patients represents a significant concern for the improvement of the quality and adequacy of provided healthcare.[1,2] The spectrum of laboratory testing overuse in the hospital setting concerns both, the initial patient evaluation and scheduled checks during the follow-up.[3] The repetition of untargeted laboratory testing during the hospital stay in clinically stable patients represents an example of low-value care which potentially can harm patients.[4] Ordering laboratory testing at regular intervals (eg, daily) or on a routine basis, could in fact lead to further unnecessary diagnostic and therapeutic procedures potentially producing stress and side-effects.[1,5] Furthermore, the interpretation of laboratory testing results without considering the pre-test probability of a disease limits the predictive value of the lab test itself, leading to an increase in false positive results and to incorrect diagnoses.[6-8] More than 50% of lab tests ordered by physicians are actually prescribed in a context of low pre-test probability or, paradoxically to reassure patients.[9] It is also known that teaching hospitals routinely order more laboratory tests for inpatients compared with non-teaching hospitals.[10-12] However, recent evidence demonstrates that advanced clinicians may be even less comfortable with limiting laboratory testing than attending physicians and residents.[13] Last but not least, it is also known that nurses including nurse practitioners may also influence the lab test ordering process.[14]

Diagnostic phlebotomies are among the predictors of haemoglobin level during hospitalisation, leading, when excessive, to hospital-acquired anaemia, and potentially to increased length of hospital stay and need for blood transfusions.[15-17] In this regard, it has been estimated that 20% of in-hospital patients develops moderate to severe anaemia, with the haemoglobin dropping from normal to <11 g/dL.[18] Furthermore local pain and haematomatas are often associated with repeated blood withdrawals, both potentially producing psychological consequences on patients.[19]

Coming back to the opportunity of limiting unnecessary laboratory prescriptions, growing evidence suggests that decreasing the amount of laboratory tests is not associated with an increase in readmission, missed diagnoses or mortality.[20,21] These data should reassure clinicians of the safety of reducing, in a structured way, non clinically oriented laboratory testing.

Several interventions have been targeted at the inadequacy of blood testing in hospitals. The most successful were those that implemented multifaceted approaches involving a combination of 3 strategies: education, audit, and feedback on provider ordering practices, and restrictive ordering options in the electronic prescription tools.[4,21-23] In the context of the Choosing Wisely Campaign, an initiative launched by the American Board of Internal Medicine aimed to target unnecessary low value investigations and treatment and to promote conversation between patients and providers, several medical societies have recommended against routine laboratory testing in hospitalised patients.[24-26] The Swiss Society of General Internal Medicine, under the name of Smarter Medicine/Choosing Wisely Switzerland, joined the Campaign in 2014 and published twice a list of five high-risk interventions to be avoided in the ambulatory and hospital care setting, respectively.[27]

What's known

- Reducing unnecessary laboratory testing in hospitalised patients is a difficult task and represents a challenge to improve the adequacy of healthcare.
- The "Choosing Wisely Campaign" is engaged in avoiding unnecessary and low value investigations. However, "do not to do" recommendations alone did not prove to be effective in influencing clinicians' prescribing (or prescription?) behaviour.

What's new

- In this before and after proof of concept study, we explored a novel multimodal approach to curb laboratory testing overuse in the hospital setting.
- We found that a web-based transparent monitoring-benchmarking, coupled with educational interventions, exposing prescriber physicians to peer comparison, can effectively lead to a durable reduction in the number of laboratory tests, in the volume of blood samples taken and in laboratory costs.

In one of these recommendations the Swiss Society of General Internal Medicine invited physicians to avoid ordering blood tests at regular intervals or to perform routine extensive lab panels without specific clinical questions.[27]

The same year, a project aimed at improving the adherence to the recommendation in a network of southern Switzerland public teaching hospitals (Ente Ospedaliero Cantonale, EOC), was launched.

In this study, we explored accordingly the efficacy of a multi-level strategy (educational plus audit and feedback plus web-based open continuous benchmarking), addressed to all healthcare providers of the internal medicine wards, aimed to reduce unnecessary inpatient laboratory testing.

The first objective of the study was to demonstrate a reduction in the number of blood withdrawals per patients following the implementation of the intervention. Secondary objectives were to demonstrate a reduction in both blood volume withdrawn and related laboratory costs.

2 | METHODS

2.1 | Design, setting, and study population

Multicentre, proof of concept, prospective, observational, before and after study conducted in the internal medicine departments of five teaching hospitals (H1, H2, H3, H4, H5) belonging to a public network called Ente Ospedaliero Cantonale (EOC), located in the Italian-speaking part of Switzerland. Data of all patients aged 18 or over, of both genders, who were admitted to any of the five internal

medicine departments, between 1 January 2015 and 31 December 2017, were analysed. Data, without patient identifiers, were collected on the basis of the standard hospital monitoring. The study, involving anonymous secondary data only, is hence exempt from review board approval by the Swiss Ethics Committee.[28]

2.2 | Study variables

The primary measure of interest was the number of blood withdrawals per patient and per day of hospital stay during the 3 years of the study. Except for arterial blood gas analysis and capillary point-of-care glucose determination, all blood withdrawals performed from admission (via emergency room or clinical wards directly) until discharge were considered.

Secondary measures of interest were: the volume of blood withdrawn per patient and per day of hospital stay and the laboratory costs per patient.

The volume of blood withdrawn was calculated on the basis of the number and type of blood vials collected. The hospitalisation length was defined as the number of days between the admission and the discharge.

The laboratory costs were calculated, in Euros, on the basis of what is internally billed to the wards.

The following variables were collected: patient demographics (age, gender), length of hospitalisation (in days), and hospital Case Mix Index (CMI). The CMI corresponds to the Cost Weights of all inpatients in a defined time period divided by the number of admissions.

2.3 | Multi-level strategy

The Multi-Level Strategy was based on three key elements:
- Web-based open unmasked continuous benchmarking.
- Educational intervention (ie, meetings, feedback).
- Inclusion of all healthcare providers of the teaching hospital network (resident physicians, senior physicians, registered nurses, attending nurses).

Web-based open unmasked continuous benchmarking. The web-based continuous benchmarking, called "Reporting Wisely," consisted in a monitoring system performing automatically a blood withdrawal benchmarking between hospital wards, unmasked and open to every health care provider of the network. The monitoring started in January 2015 but was opened to every member of the staff only in January 2016. The web-based clinical support recorded continuously, updating the data weekly, the number and volume of blood withdrawals for every ward of the network up to the unit level, providing a trend of the evolution of the laboratory prescriptions and a benchmarking with the other units and wards of the network. The "Reporting Wisely" tool was presented as a user-friendly web-based interface, able to provide updated graphics of laboratory prescription trends. The application was available for continuous consultation by physicians and nurses of the internal medicine departments.

Educational interventions (ie, meetings, feedback). Senior professional leaders of each hospital, including nurses and physicians, were selected to ensure a continuous training on the adequacy of laboratory prescriptions. Every 3 months "experts" meeting were organized, in which educational reminders on the importance of accurate laboratory prescriptions and feedback on the laboratory test use trends were provided. "Experts" consisted of senior physicians specialized in internal medicine, senior laboratory physicians, biostatisticians and patient quality and safety managers. Healthcare providers at different levels (senior physicians, young physicians, nurses with a wide range of work experience) were the target of the interactive learning meetings. The principal goal of these meetings was to encourage the participants to order lab tests in a reflective and targeted way based on clinical indications. During educational meetings, an attendance register was also kept to ensure that all providers involved received training.

During the educational meetings 3 key messages were emphasized:
- Repetitive testing has potential side effects (eg, patient discomfort, local pain, hematomas, hospital-acquired anaemia, cascade of further inappropriate tests, costs).
- Clinically oriented laboratory tests are as safe as prescheduled ones or routines and are not associated with delays or misdiagnosis
- Comparing one's own clinical attitude in lab prescriptions with the institutional benchmark of the hospital network can help to build more awareness of one's own habits, enhancing the change.

Inclusion of all healthcare providers involved in the care of the internal medicine patients. To change the prescription habits on the wards a multi-professional approach involving physicians and nurses was chosen. Educational meetings were based on pro-active interaction between professional groups, stimulating discussion to define critical points in the enforceability of laboratory prescription recommendations.

2.4 | Data analysis

Data were analysed using the R studio software (Version 0.99.467). Categorical variables are presented as numbers and percentages, while continuous values are presented as median and interquartile range (Q1-Q3). The mean number of blood withdrawals as well as the volume of blood taken per patient and per day of hospitalisation, were analysed across the study years. Variations in the number of lab tests, volume of blood withdrawals and costs per patient and per day of hospitalisation during the hospital stay in the internal medicine departments were analysed and compared considering the quarterly time segments. A segmented regression analysis of interrupted time-series was used to estimate the changes in levels and trends of laboratory test prescriptions and blood volume withdrawn with lab tests before and after the introduction of the intervention.

Partial autocorrelation function was examined to determine whether a specific adjustment was required. Serial autocorrelation

TABLE 1 Characteristics of the study population for the period 2015-2017

|	Internal medicine departments
Total admissions (n)	33.309
Total patients (n)	22.198
Admission H1, n (%)	3.840 (11.5)
Admission H2, n (%)	6.299 (18.9)
Admission H3, n (%)	8.387 (25.2)
Admission H4, n (%)	7.270 (21.8)
Admission H5, n (%)	7.513 (22.6)
Age, y (median, IQR)	76 (63-84)
Age groups, n (%)	
<65, y	8.869 (26.6)
65-80, y	12.701 (38.2)
>80, y	11.739 (35.2)
Gender, females (%)	16.639 (50.0)
Case-mix (median, IQR)	0.71 (0.51-0.93)
Number of blood test (median per patient, IQR)	33 (22-49)
Volume of blood withdrawals (median per patient, IQR)	27 (19-42)
Number of blood test per day of hospitalisation (median, IQR)	4.8 (3.2-7.0)
Volume of blood withdrawals per day of hospitalisation (median, IQR)	4.1 (2.9-5.9)
Costs, CHF per day of hospitalisation	58.6 (33.5-97.2)
Costs, CHF (median, IQR) per patient	408.4 (223.4-707.1)

in the regression models was tested using the R's GLS function from the NLME package in the fitted segmented regression.

For the time series regression equation we also calculated: the β0 coefficient, which estimates the level of lab test prescriptions, blood volume and costs at the beginning of the observation; the β1 coefficient, which estimates the baseline trend before the intervention; the β2 coefficient, which estimates the change in lab test prescriptions, blood volume and cost level during the intervention, and the β3 coefficient, which represents the change in the slope of the trend of lab test prescriptions, blood volume and costs after the start of the intervention. In all models the 95% relative confidence intervals and associated *P*-values were also shown. The statistical significance for all outcomes was set at *P*-value <0.05.

3 | RESULTS

3.1 | Demographic and clinical characteristics of the study population

The demographic and clinical characteristics of the study population over the 3 years of the monitoring-intervention period are presented in Table 1. A total of 33 309 admissions were analyzed (22 198 patients). The median age was 76 years (Q1-Q3, 63-84). Genders were similarly represented (females 50%). The median (Q1-Q3) number of lab tests per patient and per day of hospitalisation was respectively: 33 (22-49) and 4.8 (3.2-7.0). The median (Q1-Q3) volume of blood taken expressed in ml/patient and ml/day of hospitalisation was respectively: 27 (19-42); 4.2 (2.9-5.9). The direct laboratory costs, expressed in Swiss francs (CHF)/*Euros* (€), per patient and per day of hospitalisation were respectively 408.4 CHF (223.4-707.1)/*358.2 € (196.0-620.3)* and 58.6 CHF (33.5-97.2)/*51.4 € (29.3-85.3)*.
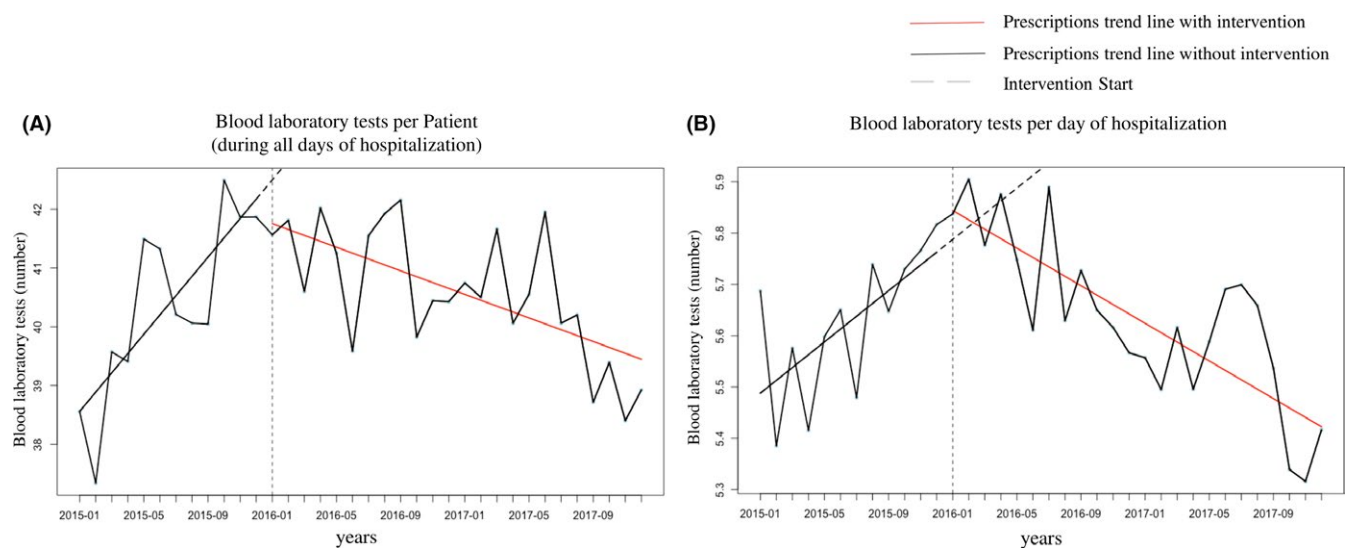
FIGURE 1 Time series analysis of the number of laboratory test per patient (A) and per day of hospitalisation (B) before and after the intervention. Monthly rate of the number of laboratory prescriptions per patient (A) and per day of hospitalisation (B) during the whole study period (solid black lines). The vertical grey dashed line indicates January 2016, the month in which the intervention was implemented. Dashed black lines indicate the prescriptions trend without intervention. Solid red lines indicate the prescriptions trend with intervention

3.2 | Time-trend analysis of the prescribed number of laboratory tests

Before the intervention, a significant constant upward trend in the monthly number of lab prescriptions per 100 admissions, with a slope of 0.328 (SE 0.074; $P < 0.001$), was found. After the implementation of the intervention the trend line decreased significantly by –0.428 (SE 0.078: $P < 0.001$) per 100 hospital admissions per month (Figure 1A). By December 2017, 12 months after the start of the intervention, we estimated that the monthly average of lab prescriptions was 11% less than that would have been expected if the intervention had not taken place. Laboratory test prescriptions per day of hospitalisation also showed a significant decrease in the slope of the trend line: –0.043, SE 0.010; $P < 0.001$; which represent a monthly relative reduction of 6% (Figure 1B). A tabular version of the Interrupted Time-Series Regression Analysis of laboratory test prescriptions is shown in Table 2A.

3.3 | Time-trend analysis of the blood volume

Before the intervention an upward trend in the monthly volume of lab prescriptions per patient was found: 0.0151 (SE 0.104 $P = 0.156$). After the implementation of the intervention a significant change in trend was shown: –0.254 (SE 0.115; $P = 0.035$) (Figure 2A). By December 2017, 12 months after the start of the intervention, we estimated that the monthly average of blood volume per day of hospitalisation was 7% less than that would have been expected if the intervention had not taken place. After the intervention, the blood volume per day of hospitalisation, also showed a significant decreasing trend: –0.025 (SE 0.008; $P = 0.003$) (Figure 2B). By December

TABLE 2 Interrupted time-series regression analysis of A) number of laboratory tests performed, B) blood volume withdrawn, C) costs per day of of hospital stay and per patient (in Swiss franks, CHF)

Variable	β coefficient	Confidence interval 95%	P-value
A) Number of laboratory tests per day of hospitalisation			
Base level (β 0)	5.463	0.0693	<0.0001
Base trend (β 1)	0.025	0.009	0.010
Change in level (β 2)	0.099	0.074	0.188
Change in trend after the intervention (β 3)	−0.043	0.010	0.0001
Number of laboratory tests per patient			
Base level (β 0)	38.232	0.545	<0.0001
Base trend (β 1)	0.328	0.074	0.0001
Change in level (β 2)	−0.315	0.611	0.609
Change in trend after the intervention (β 3)	−0.428	0.078	<0.0001
B) Blood volume per day of hospitalisation			
Base level (β 0)	4.766	0.055	<0.0001
Base trend (β 1)	0.011	0.008	0.167
Change in level (β 2)	0.0213	0.062	0.736
Change in trend after the intervention (β 3)	−0.025	0.008	0.003
Blood volume per patient			
Base level (β 0)	34.654	0.794	<0.0001
Base trend (β 1)	0.151	0.104	0.156
Change in level (β 2)	−0.089	0.820	0.913
Change in trend after the intervention (β 3)	−0.254	0.115	0.0352
C) CHF per day of hospitalisation			
Base level (β 0)	72.234	1.8606435	<0.0001
Base trend (β 1)	0.542	0.2529265	0.0397
Change in level (β 2)	−0.190	2.0793401	0.9277
Change in trend after the intervention (β 3)	−0.581	0.2679803	0.0376
CHF per patient			
Base level (β 0)	507.6838	18.1313	<0.0001
Base trend (β 1)	8.295	2.447	0.002
Change in level (β 2)	27.686	20.022	0.176
Change in trend after the intervention (β 3)	−8.128	2.620	0.004
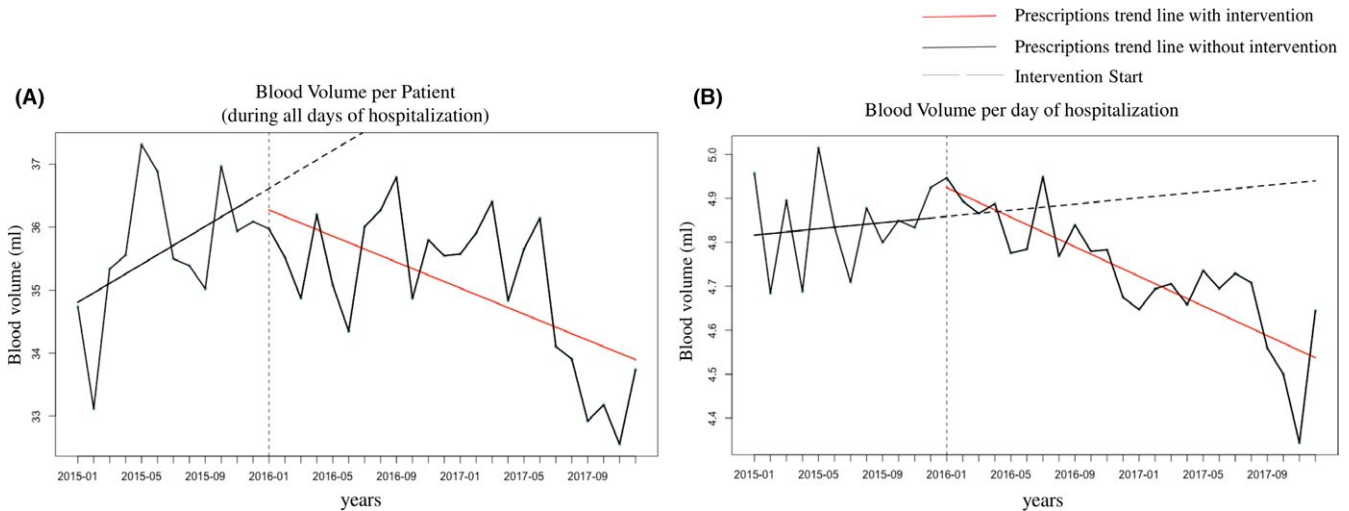
FIGURE 2 Time series analysis of the blood volume withdrawn per patient (A) and per day of hospitalisation (B) before and after the intervention. Monthly rate of the volume withdrawn per patient (A) and per day of hospitalisation (B) during the whole study period (solid black lines). Vertical grey dashed line indicates: intervention start. Dashed black lines blood volume trend without intervention. Solid red lines indicate blood volume trend with intervention

2017, we also estimated that the monthly average of blood volume was 3% less than that would have been expected. The interrupted time-series regression analysis of the blood volume taken is shown in Table 2B.

3.4 | Time-trend analysis of laboratory costs

After the intervention, a significant decrease in direct lab costs was found. A change in trend was observed for the lab costs per patient with a slope of −8.128 (SE 2.620; P = 0.004), which represents 17% of relative reduction (Figure 3A). A significant reduction in daily trend costs was also found: −0.581 (SE 0.267; P = 0.037), which represents 7% of relative reduction (Figure 3 B; Table 2C).

4 | DISCUSSION

Redundant and unnecessary laboratory tests have been considered to result in an undesired cascade of further diagnostic procedures, over-diagnosis and avoidable costs worldwide.[29,30] The Choosing Wisely Campaign engages physicians and patients in identifying and avoiding unnecessary and low value investigations and treatments. In our Hospital Network, we have been using Choosing Wisely as a springboard for the development of initiatives aimed to optimise the adequacy of healthcare acting specifically on health care waste.[31,32] The implementation of a centralised web-based system, accessible to every health care provider involved in the care of the hospitalised patients, delivering unmasked data, called "Reporting Wisely," yielded substantial reductions in the number of lab tests
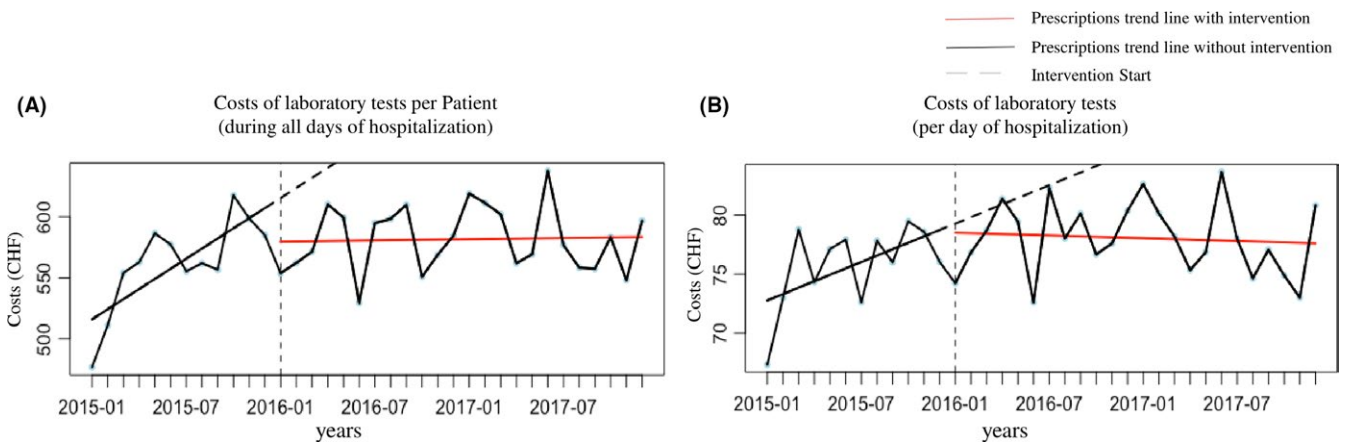
FIGURE 3 Time series analysis of the costs in Swiss francs (CHF) per patient (A) and per day of hospitalisation (B) before and after the intervention. Monthly rate of costs in CHF per patient (A) and per day of hospitalisation (B) during the whole study period (solid black lines). Vertical grey dashed line indicates: intervention start. Dashed black lines indicate costs trend without intervention. Solid red lines indicate costs trend with intervention

and volume of blood withdrawals per patient (primary and secondary outcome, respectively). We feel that, beyond educational interventions, the peer pressure generated by the continuous open benchmarking played a determinant role in the success of our strategy.[33] The direct laboratory costs showed a significant growth reduction (secondary outcome); we have however to acknowledge that we have only stopped the growing in the request of tests and that we are probably still far away from a reasonable baseline.

Our intervention has to be seen as a proof of concept study; the computer-based reporting system could in fact be further developed. Integrating it with an educational capillary approach delivering targeted messages to users could further increase the impact of the continuous benchmarking process. The fact that attempts in reducing laboratory testing are more efficient using multifaceted approaches especially if integrated education, process changes, feedback on costs, and financial incentive are involved, was established in previous studies.[34,35] However, most of them have focused on reducing the use of a limited number of laboratory tests.[36,37] Our results highlight how a web-based unmasked open monitoring-benchmarking system exposing individual health care providers to peers, coupled with educational interventions, may produce a significant effect on the prescription of a variety of laboratory tests. Last but not least, we highlight the favourable cost-effectiveness of our intervention at the department level. The costs incurred in terms of training and learning working hours and those related to the implementation of the IT system would only need about 2 years of laboratory costs saved to be counterbalanced. The computer platform implemented was however designed and used to monitor not only laboratory tests but also medications (benzodiazepines, proton pump inhibitors, neuroleptics, opioids, and corticosteroids),[31,32] allowing for further potential cost reductions and a more favourable cost effectiveness balance. We have however to acknowledge that at the institutional level the effective laboratory cost savings (related to reagents, single use materials, and wear of laboratory equipment) were only about 20% of the amount billed to the wards as the personnel costs and part of the operating costs were not reduced. This means that, at the institutional level, only long lasting reductions in laboratory test consumption can translate into significant cost and personnel savings.

Some further limitations of our study have to be mentioned. Firstly, we did not provide a randomised design; therefore, we cannot demonstrate causation between the implementation of the web-based continuous survey and the outcomes. Secondly, we cannot estimate whether the reduction in blood withdrawals observed translates into better health outcomes (ie, reduction of hospital induced anaemia, in blood withdrawals related pain and in in-hospital anxiety).

In conclusion, our pilot study showed that an open web-based system, involving all health care providers, coupled with educational interventions, could be a helpful tool to generate awareness of prescriber habits and to catalyse changes in their behaviour. The peer pressure related to the unmasked benchmarking process probably played a determinant role. Thanks to the proposed approach, the number of laboratory tests, the blood volume withdrawn and the related costs were reduced in a significant as well as sustained way.

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