Role of the Novel Integrated Clinical Pharmacist Menu Software in Improving Medication Therapy Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Medication therapy management (MTM) continues to offer pharmacists the opportunity to use their knowledge, assist patients and caregiver in improving therapeutic outcomes, however the change is slow. Health information technology has been noted as an important driver in the success of MTM and has a potential role in improving therapeutic outcomes and reducing medication errors.
Objective: This research aimed to design an integrated clinical pharmacist menu (CPM) software along with clinical decision support tools, optimizing MTM services and reducing medication errors.
Methods: The integrated CPM software was designed abridged with decision support tools. A comparative study was conducted in a setting of integrated CPM software versus paper-based clinical pharmacy services (P-CPS) for the evaluation of MTM services. Clinical decision support systems (CDSS) and automated significant laboratory and medication alerts were analyzed for the

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improvement of MTM and impact on the identification and resolution of medication errors.
Results: MTM improved after the application of the CPM software with a difference of 100% in "medication history generation" and "patient care plan," with a reduction in medication errors by 39.8%. The identification of medication errors and verification of medication order significantly improved from 49% to 82% (p = 0.00) and from 4.5% to 7.0% (p = 0.00), respectively, in the CPM setting. The CDSS tool in the CPM software generated 730, 1802, and 198 auto alerts for "drug–drug interaction," "inappropriate dose," and "dose adjustment in an abnormal clinical laboratory test," respectively, which improved the resolution and identification of medication errors.
Conclusion: The CPM is user-friendly, which improved the MTM services. Medication error identification and resolution were significantly improved by the CPM software.

1. INTRODUCTION

MTM is a distinct service that optimize therapeutic outcomes for individual patients. While there is enthusiasm for the benefits of MTM, there are limited formal organizational and framework within the hospital pharmacy to support it [1]. A challenge that affects MTM delivery across the health care continuum is technology. Despite the existence of numerous pharmacy information systems (PIS), the access to medical records, integrating of pharmacy system into the health information technology infrastructure has been difficult and adoption of shared electronic health record systems has been minimal [2-3]. In Pakistan, hospital pharmacy services are in the development stage; however, some of the private hospitals have already initiated the application of hospital pharmacy services. A few of them have used hospital information systems for inventory management, financial accounts, and selling of medication, whereas some are equipped with computerized physician order entry (CPOE) and automated dispensing systems. In 2000, the adoption rate was slow, but by 2007, more than 80% of institutions adopted health information technology (HIT) [4]. Janinah and Niesha have emphasized that the success of PIS implementation depends on its design, quality, and functionality, as well as communication among its users [5].

Clinical pharmacy interventions are always considered to have a valuable contribution to the process of patient care as they decrease medication errors and rationalize medication therapy. Automated alerts have played a significant role during the medication therapy management (MTM). Automated alerts remind pharmacists to act against incorrect dose, review drug–drug interactions, review the medication if it is contraindicated, clinical laboratory interaction if

any through artificial intelligence decisions. It is further emphasis that automated alerts help the clinical pharmacist to raise/address correction (also called as clinical pharmacy intervention) if there is an error in the MTM. The electronic prompt embedded within antibiotic stewardship intervention in patients with gram-negative bacteremia positively influenced the time to appropriate therapy, length of stay, and mortality and should be a focus of antimicrobial stewardship programs [6]. The safety features of electronic patient medical record systems are effective in alerting the end users about the potential clinical hazards and errors during pharmacy order entry. System integration is an information technology or engineering process that physically or functionally links and combines the components of different subsystems and software applications in one system or acts as a coordinated whole [7].

The best-of-breed pharmacy software is fully integrated with electronic health records, electronic medication administration suite, patient information, and other clinical systems with enhanced features of the decision support tool. However, some of the essential features lack the prevailing PISs (see Table 1 for a detailed analysis of the PISs developed worldwide).

This research focuses on the design and development of an integrated clinical PIS called a clinical pharmacist menu (CPM) in a hospital information system to reduce medication errors and improve the MTM.

2. METHODS

The CPM software was developed for 8 months by the management information system team of Shaukat Khanum Memorial Cancer Hospital & Research Center, Lahore, Pakistan, in collaboration with the investigator in a hospital

Table 1. Review of the functions of international pharmacy information system and clinical pharmacist menu of the SKMCH&RC Hospital

Software features	Pharmacy information system software [8-16]									
	Medi-tech's	Horizon Meds Manager	PharmNet - Cerner Store	Epic	CPSI	Siemens Pharmacy	Rx-Connect	Mediware - WORx	FSI Management system	SKMCH&RC
CPOE	√	√	√	√		√	√		√	√
Medication's protocol		√						√		
Alerts / Pop ups	√	√	√				√			√
Integrated system	√	√	√	√	√	√	√			√
CDSS				√		√		√		√
ADR reporting and monitoring			√			√				√
Drug data bank		√	√			√	√			√
Automated checks										
Dose		√	√			√				√
Drug allergy		√	√			√	√			√
Drug–drug interaction		√	√			√	√			√
Drug–disease Interaction		√								√
Therapeutic duplication		√				√				√
Clinical notes (Lab, Radiology)	√	√	√	√	√	√	√	√	√	√
Clinical Pharmacist Menu										√
Patient care plan										√
Chemo protocol										√
Automated significant lab. Alerts										√
Drug laboratory Intervention										√
CDSS - DVT prophylaxis drug										√
CDSS - PC order										√

CPOE = Computerized physician order entry, CDSS = Clinical decision support system, ADR = Adverse drug reaction, DVT = Deep vein thrombosis prophylaxis drug, PC = Palliative care medicine, √ = available, SKMCH&RC = Shaukat Khanum Memorial Cancer Hospital & Research Center

information system, developed in-house; using a product of Oracle Corporation, Redwood Shores, CA, USA. The design and framework, including the decision support functions, of the CPM software was pragmatically evaluated by the software engineers. Drug databases were collected using the Lexicomp USA drug data bank software and drug product leaflets, including the manufacturer's monographs. All significant laboratory formulae, including the laboratory range values, drug doses, and drug interactions, were reviewed and entered in the system using the data bank software of Lexicomp USA [17]. Auto alerts were developed within the CPM, which includes drug allergy, dose, drug- laboratory, drug-drug interaction, palliative drug order, and deep vein thrombosis prophylaxis drug.

A prospective (questionnaire-based) study was conducted to evaluate the CPM software and to review its specific functions. The CPM software was compared with paper-based clinical pharmacy services (P-CPS) by reviewing the relevant electronic and paper health records of 12 months. The usability and acceptability of the CPM software were evaluated using Shneiderman's questionnaire method and Hix & Hartson's usability specification testing procedure [18-19]. A modified nominal group consensus methodology was employed to validate the questionnaire, where the suggestions of three panelists were reviewed until all agreed [20]. A total of 15 participants were randomly selected from three different pharmacy positions, namely, clinical pharmacist, staff pharmacist, and resident pharmacist. All participants were required to study the CPM software, including the relevant integrated modules (patient care plan (PCP), medication history, medication order, and clinical alerts), in terms of clarity and feasibility and answered the questions. In order for MTM to achieve consistent positive outcomes for patients', a descriptive study was designed to evaluate the capability of the CPM software to formulate comprehensive patient care plan, to identify and resolve medication errors as well as the impact of the auto alert system during the medication order verification process, follow-up and discharge notes. The clinical pharmacy interventions in CPM and P-CPS were compared, and the impact of CDSS (during drug-drug interaction, in-appropriate dose, Dose adjustment in abnormal clinical laboratory, and deep vein thrombosis prophylaxis drug order) was analyzed in optimizing MTM.

2.1 Statistical Analysis

A descriptive statistic was used for data related to the CPM software and P-CPS, including the questionnaire's feedback data. Kolmogorov–Smirnov statistics were utilized to assess data normality. Pearson's correlation coefficient and independent samples t-test were applied to determine whether the means in the CPM and P-CPS on one metric variable (pharmacist medication order verification, medication history generation, medication error identification and resolution, and PCP formulation) are equal or not. The SPSS 20 software was used for data analysis in the current research.

2.2 Development

The development was initiated with a perceived framework after reviewing the international clinical PISs (please see Table 1) and incorporation missing essential components of MTM. The missing features for comprehensive MTM services included the PCP, pharmacist follow-up notes, HIT tools that helps in improving therapeutic outcome of patients includes CDSS, drug allergy alerts, and automated abnormal clinical laboratory test alert to the clinical pharmacist. The first task was to develop an adequate picture, which led to many hours of sessions with clinical and administration experts. Equipped with different ideas, a review of international pharmacy software, and ready access to expert knowledge, an integrated design was instigated (please see Exhibit 1). Fuzzy logic and analysis design, including "If–Then–Else," were a few of the examples of an intelligent system used to address the complexity associated with the system. Debugging of the CPM software was performed before and during the implementation phase.

3. RESULTS

On a scale of 0 to 10, the response of the participants to the CPM design was positive in terms of clarity (8.6), usability (8.4), feasibility (8.9), decision-making (9.0), and knowledge enhancement (8.9) (please see Table 2). The number of clinical pharmacy intervention using the CPM software was higher compared with that using the P-CPS (7% vs. 4.5%). The rates of acceptance of clinical pharmacy interventions using the CPM software and P-CPS were 90.7% and 84.4%, respectively (please see Table 3).

Table 2. Summary of the response of clinical pharmacist menu questionnaire among all three groups (clinical pharmacist, staff pharmacist, and resident pharmacist)

Evaluation parameters	Scale	Mean				Mean overall	Using one scale for positioning
		Max	Clin RPh (n=5)	St. RPh (n=5)	Res RPh (n=5)	± SD	
Clarity	0 1 2 3 4 5 6 7 8 9 10 NA	10	8.7	8.3	8.7	8.6 ±0.2	8.6
Usability	0 1 2 3 4 5 6 7 8 9 10 NA	0	1.8	1.4	1.6	1.6 ±0.2	8.4
Feasibility	0 1 2 3 4 5 6 7 8 9 10 NA	10	9.08	9.15	8.53	8.9 ±0.3	8.9
Decision-making	0 1 2 3 4 5 6 7 8 9 10 NA	10	9.1	9.3	8.7	9.0 ±0.3	9.0
Knowledge enhancement	0 1 2 3 4 5 6 7 8 9 10 NA	0	1.3	0.6	1.3	1.1 ±0.4	8.9

Max = Maximum, SD = Standard deviation, NA = Does not apply, Clin RPh = Clinical pharmacist, St. RPh = Staff pharmacist, Res RPh = Resident pharmacist, CPM = Clinical pharmacist menu, n = number of participants

Table 3. Clinical pharmacy interventions and outcomes recorded in the clinical pharmacist menu and existing computerized cum paper-based clinical pharmacy service setting

Activity	CPM	P-CPS
Total number of orders	162,383	98,904
Total number of interventions recorded	11,330	4,461
Total number of interventions accepted	10,271	3,766
Total interventions recorded (%)	7.0	4.5
Interventions acceptance rate (%)	90.7	84.4

CPM = Clinical pharmacist menu, P-CPS = Paper-based clinical pharmacy services
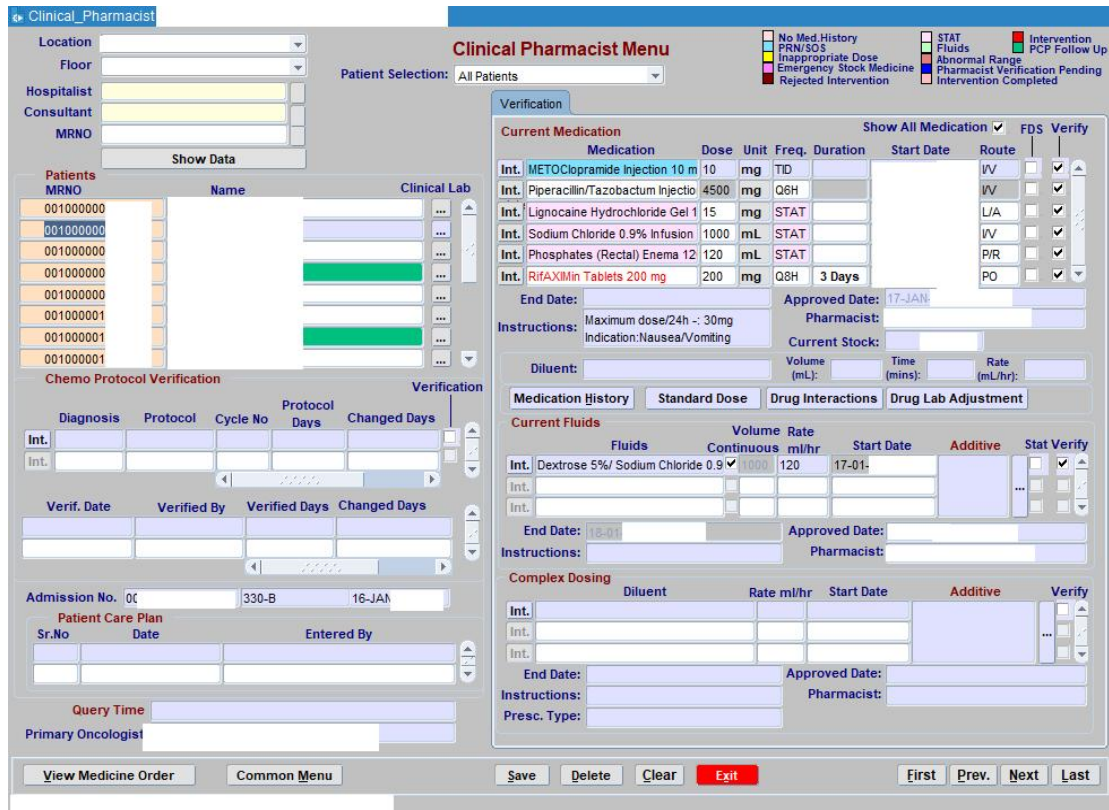
Exhibit 1. Clinical pharmacist menu screen–showing different features of medication therapy management

The medication errors identified using the CPM software and P-CPS were 11330 and 4461, respectively. The medication errors identified during the medication order verification process were high using the CPM vs. P-CPS (7.0% vs. 4.5%, respectively). The rate of medication order resolution during the medication order verification process was higher using the CPM software than that using the P-CPS (90.7% vs. 84.4). Overall, a difference of 6.3% in terms of the improvement in medication error resolution was observed in the CPM setting (please see Table 4). *The medication order resolution using the CPM software was significantly different from that using the P-CPS (P = 0.00).*

It was determined that all "drug-drug interaction" type of clinical pharmacy intervention raised were due to CDSS generated automated alerts. There were 1802 and 198 automated alerts of "inappropriate dose" and "dose adjustment in an abnormal clinical laboratory" to the clinical pharmacist, respectively, during the medication order verification process (please see Table 5). Overall, 53% of "inappropriate dose"-related

intervention was achieved because of the CDSS generated alert.

The MTM services were improved after the adoption of the CPM software, with a difference of 100% in the "PCP." An improvement of 40.2% was achieved in terms of "medication order verification" and 35.7% in terms of "medication error identification." The "follow-up" notes, "clinical pharmacist discharge notes," "drug allergy alert to clinical pharmacist," "automated abnormal clinical laboratory test reviewed by the clinical pharmacist," "auto clinical alert to the clinical pharmacist," and "CDSS" were designed and embedded in the CPM setting. However, these were missing in the P-CPS setting and hence were incomparable.

A total of 30324 automated abnormal clinical laboratory tests were reviewed by the clinical pharmacists, and 585 drug allergy alerts were generated to the clinical pharmacist in the CPM setting. Also, 4529 automated clinical alerts were generated to the clinical pharmacists, including 1802 alerts of inappropriate dose. The trend of

Table 4. Comparison of medication error resolution in the clinical pharmacist menu and paper-based clinical pharmacy service setting

Setting	Medication order	Medication order reviewed	*Medication orders with error	Medication errors resolved by clinical Pharmacist		Improvement in medication error resolution	*p-value
	(n)	%	(n)	(n)	%	%	
CPM	162,383	100	11,330 (7%)	10,271	90.7	6.3	0.00
P-CPS	98,904	100	4,461 (4.5%)	3,766	84.4		

*(n) = number, % = percentage, CPM = Clinical pharmacist menu, P-CPS = Paper-based clinical pharmacy services; *Independent samples t-test. Significant if p-value < 0.05 (two-tailed); **Errors identified during the medication order verification process only*

Table 5. Clinical decision support alert and their association with clinical pharmacy interventions

Type of medication error	CDSS alert	Clinical pharmacy intervention (total)	Clinical pharmacy intervention		Clinical pharmacy intervention due to CDSS alert	
			Accepted	Rejected		
			(n)		(n)	%
Drug–drug Interaction	730	560	510	50	730	100*
Inappropriate Dose	1802	3,804	3,545	259	1,802	53%
Dose adjustment in abnormal lab**	198	198	-	-	198	
Total	2,730	-	4,055	309	2,730	-

*(n) = number of occurrences, P-CPS = Paper-based clinical pharmacy services, CDSS = Clinical decision support system; *All drug interactions related to clinical pharmacy intervention done due to the CDSS alert. However, the number of alerts are high in comparison with the number of clinical pharmacy intervention because it is at the discretion of the clinical pharmacists to raise clinical pharmacy intervention based on clinical judgment and patient health condition.;** The alert of "dose adjustment in abnormal clinical laboratory test" was recorded under "inappropriate dose" type of the clinical pharmacy intervention header*

Table 6. Summary of improvement in medication therapy management after the implementation of a clinical pharmacist menu and its comparison with paper-based clinical pharmacy

Clinical pharmacy parameters	unit	CPM	P-CPS	Improvement (difference in %)	*p-value / r
Functions available both in CPM and P-CPS setting					
Medication order verification	%	82	49	40.2	0.00 /0.74
Medication history generation (complete)	%	17	0	100	0.00/-0.46
Patient care plan formulation (complete)†	%	4	0	100	0.00/-0.21
Medication errors identification	%	7.0	4.5	35.7	0.00/0.65
Unique functions of clinical pharmacist menu**					
Follow-up of patient notes alert	%	78.9	-		
Clinical pharmacist discharge notes	%	100	-		
Drug allergy alert to clinical pharmacist	n	585	-	***	-
Automated abnormal clinical laboratory test review by clinical pharmacist	n	30,324	-		
Auto clinical alert to clinical pharmacist	n	4,529	-		
Clinical decision support systems					
Drug–drug interaction	n	730	-		
Inappropriate dose	n	1,802	-		
Dose adjustment in abnormal clinical laboratory	n	198	-		
Palliative care medicine drug order	n	595	-	***	-
Deep vein thrombosis prophylaxis drug order	n	619	-		

*(n) = number of occurrences, %= percentage, CPM = Clinical pharmacist menu, P-CPS = Paper-based clinical pharmacy services OPD = Out-patient department, IPD = In patient department, r = Pearson's correlation coefficient;*significant if p-value < 0.05 (two-tailed);**Unique functions of clinical pharmacist menu. These were not present in the paper-based setting; ***non-comparable; † Patient care plan were formulated for selected patients only.*

medication order verification in the CPM setting was significantly different from that in the P-CPS setting (P = 0.00, Pearson Correlation 0.74), including other CPM functions (medication error identification). The correlation of medication order verification with CPM and P-CPS is 0.74. By squaring the correlation and then multiplying it by 100, the CPM medication order verification shares about 55% of its variability with the P-CPS medication order verification. The medication history and PCP of the CPM are not correlated and have negative values; hence, they do not share any variability with medication history and PCP of P-CPS, respectively (please see Table 6).

4. DISCUSSION

MTM optimization is one of the primary responsibilities of pharmacists. The American Society of Health-System Pharmacists encourages pharmacists to engage in MTM, immunization, medication ordering and administration, ward rounds, and other patient care activities permitted by law or required by the hospital [21]. The development of PCP within the CPM software has improved the consistency of MTM for all admitted cancer patients. In our study, clinical pharmacists followed an average of 78.9% of documented PCPs, with an average of four follow-ups per patient. Such a high rate was due to an automated reminder, which an application of the CPM module. The medication review process is linked with the decision support module, which alerts the clinical pharmacist in terms of inappropriate dose, drug–drug interaction, drug lab adjustment, and patient drug allergy. The electronic PCP significantly improved the degree of completion of all sections of the PCP. It is comparable to a study conducted in Scotland, in which the electronic PCP significantly improved the level of formulation [22]. For a seamless MTM of patients, an automated electronic PCP is an ideal web-based system. It is capable of capturing data at the point of care and instantly provides correct information at the right time and place to the clinical pharmacist. The web-based PCP significantly improves the collaboration between healthcare professionals and patients, which is an important part of MTM [23].

It is statistically convincing that the use of the CPM software significantly reduces the medication errors, improves medication therapy management, and helps in the clinical decision-making during patient monitoring. The

employment of CDSS has been promoted owing to its potential to improve healthcare quality and to reduce medication errors [24]. The CPM software was integrated with other clinical modules of the hospital, including physician notes, patient laboratory data, medication order entry, patient vital signs, medication administration, electronic health records, and pharmacy billing system. It has been observed that automated pharmacy systems, automatic prescription, and integration of relevant modules result in the safe use of medications [25]. In our study, the clinical pharmacist verified 82% of the medication orders during the medication chart review. This value is much higher than that of the conventional paper-based medication order system, which was 49%.

The frequency of medication history was low using the CPM software; however, the accuracy of obtaining the medication history was very good. All medication histories were complete in all aspects as the CPM software helped the clinical pharmacist in completing the required fields. Accuracy was the primary objective in designing the CPM software as the factors involved in the medication errors upon hospital admission, such as inaccurate medication histories due to wrong drug reporting history by a patient, may cause the patient to not bring their medication or be unaware about the recent medication and avoid reporting use of alternate or self-medication [26].

The recording of relevant patient medication information in the form of follow-up pharmacist notes (78.9%), medication order verification (82%), and clinical pharmacist discharge notes (100%) within the system was quite high in the CPM setting. It is noteworthy that the findings in Ursula's study entitled "Pharmacy Services to UK Emergency Departments in 2010" revealed that only 40% of the required medication information was recorded in the PIS. This suggests that the capabilities of the PIS to help decrease medication-related complications, drug–drug interactions, and inventory management have not been managed properly or are ignored, or it could be that the system is not user-friendly [27]. However, it is statistically convincing ($P = 0.00$) that the current CPM software improved the MTM delivery in terms of drug verification process and medication review process and helped in the clinical decision-making during patient monitoring.

In the current study, a total of 4529 clinical alerts were generated over 1 year, which comprised of drug allergy, dose, drug–drug interaction, palliative care drug, drug lab adjustment, and deep vein thrombosis prophylaxis drug. The results revealed that automated alerts helped prevent medication errors and are consistent with numerous studies. It has been identified in many studies that practitioner performance has improved after the implementation of CDSS [28]. Furthermore, automated alerts and reminders decrease dependence on memory and assist in decision-making and hence reduction in medical errors, which eventually enhances the patient's quality of life [29].

An automated system equipped with CDSS helps reduce errors and ultimately improves the patient's quality of life. Moreover, clinical knowledge and proper decision support tools have now become pivotal in providing patients with the best care [28]. It was identified that in the three types of clinical pharmacy intervention, namely, the drug–drug interaction, inappropriate dose, and dose adjustment in abnormal clinical laboratory test, CDDS helped in terms of auto alert to the pharmacist in raising interventions. Such support tools were absent in the P-CPS setting.

Almost all interventions related to drug-drug interaction (730 alerts) were raised because of CDSS during medication order verification. Appropriate recommendations of clinical pharmacy intervention helped in increasing the rate of acceptance (90.7% vs. 84.4%), which is only possible after the implementation of CDSS. The use of CDSS has been promoted owing to its potential to improve healthcare quality and to reduce medication errors [24].

5. CONCLUSION

The CPM software has been quite successful in terms of clarity, usability, and acceptability. This software improved the MTM specifically in the identification and resolution of medication errors. Furthermore, CDSS with automated alerts improved the medication verification process and the frequency of clinical pharmacy interventions, which is an essential tool for reducing medication errors.

6. STUDY STRENGTHS AND LIMITATIONS

The use of the novel CPM software can supplement the traceability of patient healthcare records and improve the timely decision of medication-related problems more accurately and comprehensively. This can improve the identification and resolution of medication errors using CDSS, which further optimizes patient medication therapy. This approach can be applied to other medication processes, including chemotherapy and parenteral nutrition.

Pharmacoeconomic/cost benefit analysis of CPM was not studied because most of the literature favors that such systems are financially viable for institutions with high net present value and low payback period. The participants of evaluation study were employees of the hospital and biasness may not be completely removed. Furthermore, the study was implemented at only one tertiary cancer care hospital, and thus the results may not be generalizable to other hospitals.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICS APPROVAL

Approval was obtained from the Bio-ethical committee of Quaid-i-Azam University, Islamabad, Pakistan, and the Institutional Review Board (IRB) of SKMCH&RC, Lahore, Pakistan. Hix & Hartson's usability testing specification tool permission was obtained, and Shneiderman's questionnaire user satisfaction questionnaire was purchased for use of the questionnaire.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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