



Clinical decision support systems for utilization of CT in the emergency department

Over the past two decades, healthcare costs have been growing at a rate that is unsustainable. Despite its vast utility, diagnostic medical imaging has been a culprit of the rising healthcare expenditure. Health information technology, particularly clinical decision support systems, has been promoted as a tool that can potentially improve the efficiency of imaging delivery by encouraging appropriateness of testing, thereby decreasing unnecessary radiation exposure and costs. Despite some promising early results, evidence of clinical decision support systems on imaging utilization in the emergency department remains sparse. Nevertheless, health information technology provides promising opportunities for translational and implementational research. Further research is needed to understand the barriers to clinical adoption and broad implementation in the community.

KEYWORDS: computerized physician order entry • electronic medical records • healthcare IT • health policy • information technology • medical informatics

Over the last decade, health information technology (HIT) has revolutionized healthcare [1]. Recent research suggests that hospitals with electronic medical records, computerized order entry and clinical decision support had fewer complications, lower mortality rates and lower costs [2]. However, how HIT has impacted diagnostic imaging utilization is unclear. The aims of this article are to examine how clinical decision support systems have affected the field of imaging, specifically, the use of CT in the emergency department and to identify key features associated with successful clinical decision support.

Information technology, diagnostic imaging & radiation exposure: progress & pitfalls

Recent advancements in diagnostic imaging have enhanced physicians' ability to diagnose diseases quickly and accurately, and have undoubtedly contributed tremendously to patient care. However, easy availability of diagnostic testing carries the risk of overutilization with resultant increased healthcare costs and medical radiation exposure [3,4]. Costs incurred by medical imaging tests are substantial. In 2007, imaging services expenditure totalled US\$11.4 billion among Medicare beneficiaries alone in the USA [101]. Advanced diagnostic imaging use has similarly increased among patients enrolled in large integrated healthcare systems from 1996 to 2010 [5]. Furthermore, in recent years, there has

been growing concern in both the healthcare and public sectors regarding possible cancer risk associated with diagnostic imaging [6,102]. The increased use of CT has resulted in a doubling of the mean per capita effective dose of radiation exposure [5], with great variation across institutions and study types [7]. The radiation exposure may be associated with future cancer risk [8]. It is estimated that as many as 29,000 cancers could be related to CT scans alone in the USA annually [9].

Beyond the immediate risk of radiation and incurred costs, there are concerns that overutilization and increased sensitivity of diagnostic testing may result in overdiagnosis – the detection of disease that otherwise would never have become relevant to the patient. Downstream effects of overutilization and overdiagnosis include unnecessary follow-up imaging, potentiating further radiation risks. Additionally, potentially harmful procedures and treatments may be the consequence [10]. For all these reasons, researchers and policy makers have called for a more judicious use of diagnostic imaging and many believe that HIT may provide an elegant solution.

Can a clinical decision support system improve outcome?

Computerized physician order entry (CPOE) is a process of order entry whereby physicians and other providers communicate instructions for the care of patients electronically over a

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computer network. An important component of CPOE is the embedded clinical decision support system (CDSS). A classic CDSS includes alerts and reminders that automatically inform the clinician of a specific action, providing real-time feedback to optimize user decisions and actions. The level of importance can be addressed in their implementation by using a variety of solutions. They can range from hard-stops that prevent providers from moving forward in the medical chart to simple educational pop-up windows or banners that pose no barrier to workflow. Thus, CDSSs can be designed to educate, encourage and enforce the use of evidence in day-to-day practice, in the hope of optimizing clinical practice. CDSSs have been shown to have a positive impact on a physician's performance, safety and outcomes in a variety of settings. In a systematic review, Garg *et al.* found that clinical decision support may improve practitioner performance through improved diagnosis, preventive care, disease management, and drug dosing and prescribing [11].

CDSSs for diagnostic imaging

Diagnostic imaging has become a popular target for the application of CDSSs to guide clinicians in a more judicious utilization of diagnostic imaging. For example, a provider may place an order of a head CT on a patient with a minor head injury and the CDSS may prompt the clinician that, in the absence of red flags, a CT scan may not be necessary based on current evidence. Initial experience shows promising impact of CPOE on some physician imaging ordering practices [12–16]. While the primary target of a CDSS is clinicians, it may also have a secondary impact on patients. CDSSs may give patients the perception that clinical decisions in imaging are based on conscientious, explicit use of current best evidence. At Massachusetts General Hospital (MA, USA), the implementation of an integrated decision support system was associated with substantial decreases in the growth of outpatient CT and US procedures [12]. The same group also subsequently found that the order-entry system was associated with a decrease in low-yield outpatient examinations, from 5.4 to 1.9% [17]. However, other groups have found varying success with CDSSs [14,18].

Diagnostic imaging in emergency departments

The increase in medical imaging is most evident in the emergency department (ED)

setting. The prevalence of CT or MRI use for injury-related conditions increased from 6% in 1998 to 15% in 2007 [19]. In one university-affiliated urban ED, the intensity of abdominal imaging examinations per 1000 ED visits increased by 2.7-fold in relative value units between 1990 and 2009 [20]. Repetitive imaging of the same patient frequently visiting the ED is a common occurrence [21,22]. Causes for the recent imaging expansion is probably multifactorial, with contributing factors including defensive medicine, uncertainty about imaging indications, self-referral by physicians and patient expectation [23–27].

Current state of HIT in the ED

The emergency department is an ideal setting to study the impact of a CDSS for several reasons. First, the American College of Emergency Physicians recognizes and endorses the potential benefits of HIT on improving the quality of emergency care, reducing medical errors and promoting patient safety [103]. Furthermore, much of current emergency medicine research focuses on the development of appropriateness of imaging. A number of clinical decision rules have been developed and validated, such as the Canadian CT head rule [28], the New Orleans Criteria [29], the Ottawa ankle [30] and knee [31] rules, and the NEXUS for cervical spine imaging [32,33]. The American College of Emergency Physicians has issued numerous clinical policy statements emphasizing the efficient utilization of diagnostic CT and practice variation in the ED [34,35]. However, the translation of the guideline policies into clinical practice remains challenging and variable [36]. CDSSs may help address some of the barriers in evidence translation and improve clinician decision-making at the point of care.

Much of the research in CDSSs in the ED has centered on pulmonary embolism (PE), repeat imaging and head CT. Please see TABLE 1 for summary of findings.

Clinical decision support system for suspected PE: less is more

Clinical prediction scores, such as the Wells Criteria, have been validated and are recommended for the diagnosis of venous thromboembolism by national guidelines [37,38]. The Wells score allows for the risk stratification of patients with suspected PE based on seven clinical data points [39]. Due to the strength of the evidence associated with Wells and its translatability to actionable automated decision

Table 1. Current evidence for the impact of clinical decision support systems on imaging use in the emergency department.

Intervention	Study design	Study size	Finding	Ref.
CT angiograms for PE				
Standalone decision support delivered electronically, along with educational sessions on specific imaging	Retrospective, before and after comparison	n = 295 (187 control; 109 intervention)	In suspected PE evaluation, the interventions resulted in a 13% overall reduction in inappropriate diagnostic practice In pre-intervention audits, 35% were not adherent to guidelines compared with 22% in the postinterventional group (p = 0.02)	[40]
Real-time delivery embedded in a CPOE based on a modified dichotomized version of the Wells criteria	Retrospective, before and after comparison	n = 434 (205 control; 229 intervention)	The implementation of CPOE-CDSS was associated with an overall increase in the positivity rate of PE, from 8.3 to 12.7%; a difference of +4.4% (-1.4 to 10.1%)	[41]
Integrated CDSS into the ED radiology CPOE system consisting of three rules based on the Wells criteria	Retrospective, before and after comparison	n = 6838 (3855 control; 2983 intervention)	CTA use decreased by 20.1% after implementation (p = 0.0379), while yield increased 69.0%, from 5.8 to 9.8% (p = 0.03)	[42]
All CTs				
Passive reminder to notify providers if a patient has received more than five CT scans within the prior 365 days	Retrospective, before and after comparison	n = 3940 (2029 control; 1911 intervention)	35% of patients had at least one CT ordered during the ED visit. There was no significant difference in ordering behavior before and after intervention (OR: 1.0 [0.87–1.15]; p = 0.98)	[43]
Head CT (along with other non-CT examinations)				
Real-time delivery of guidelines written by the CERF	Time-series design with three control periods and three intervention periods of 1-month duration	n = 1024 (head CT)	The proportion of radiology orders that did not conform to guidelines decreased from 33.2 to 26.9% with CDSS (p ≤ 0.01)	[44]
CDSS: Clinical decision support system; CERF: College des Enseignants de Radiologie de France; CPOE: Computerized physician order entry; CTA: CT angiography; ED: Emergency department; OR: Odds ratio; PE: Pulmonary embolism.				

support, chest CT angiography (CTA) in patients with suspected PE has received considerable attention as a study of target for CDSSs.

In one single-institution study, Bairstow *et al.* developed and implemented a standalone electronic application called the diagnostic imaging pathway to deliver decision support to assist clinicians in choosing the most appropriate imaging exam [40]. Four clinical conditions were targeted: suspected PE, ankle injury, suspected renal colic and nontraumatic acute abdominal pain. Using a retrospective observational study design, the authors were able to demonstrate that a simple CDSS intervention resulted in a 13% overall reduction in inappropriate diagnostic imaging for suspected PE. Up to 35% of studies were not adherent to guidelines in the pre-intervention audits compared with only 22% in the postinterventional group (p = 0.017).

Drescher *et al.* also assessed how CDSSs can impact inappropriate imaging by integrating real-time delivery into its CPOE in patients with suspected PE [41]. The investigators implemented a mandatory pop-up window that provided a Wells score calculator and automatically provided

recommendations based on the prediction score. Implemented in one ED over a 4-month study period, the CDSS resulted in a trend towards enhanced yield of chest CTA, but the difference was not statistically significant. A review of 434 CTA examinations found the study-positivity rate was 8.3% in the pre-intervention period, compared with 12.7% postintervention, with a difference of 4.4% (95% CI: -1.4 to 10.1%). Unfortunately, their CDSS was poorly accepted by emergency physicians, resulting in poor adherence to the CDSS and it being discontinued from the CPOE after study completion. When asked, reasons given for nonadherence to the computerized decision support system algorithm included too much time spent at the computer and away from the patient and a lack of belief that the computerized decision support system was helpful for guiding patient evaluations.

Using a similar before and after comparison study design, Raja *et al.*, at their academic ED, retrospectively analyzed data from the radiology database, as well as radiology reports, for the presence/absence of PE [42]. They found that a CDSS is associated with a significant decrease in

utilization, as well as an improvement in the yield of CTAs. The quarterly use of CT rose 82.1% before implementation of CDSS, from 14.5 to 26.4 CT scans/1000 patients ($p < 0.0001$). After implementation of CDSS, quarterly use decreased by 20.1%, from 26.4 to 21.1 CT scans/1000 patients ($p = 0.04$). Of all the CTAs performed during this 6-year period, the yield by quarter increased from 5.8 to 9.8% subsequent to the implementation of CDSS ($p = 0.03$).

Reducing radiation: can knowledge change behavior?

Reducing unnecessary radiation exposure to patients has been a priority ever since evidence has shown that radiation is associated with an increased cancer risk. One study examined how a passive reminder to notify providers if a patient has received more than five CT scans within the prior 365 days may influence their ordering behavior. Horng *et al.*, in their single-institution study, retrospectively compared 2029 patients in the preintervention period with 1911 postintervention [43]. They found that the passive reminder resulted in no significant change in physician ordering patterns ($p = 0.98$, odds ratio: 1.0), even after adjusting for age, gender, disposition, acuity, number of consults, days since last ED visit and days since last CT ordered.

CT of the head: implementation of guidelines

Through a time-series study, Carton *et al.* made appropriate guidelines available to practitioners on alternating months during a 6-month study period in two European EDs [44]. During intervention months, onscreen reminders were displayed to illustrate the appropriate recommendations concerning the clinical context, and practitioners were alerted if requests did not conform to guidelines. The availability of guidelines in the CPOE system decreased the percentage of radiology orders that did not conform to guidelines from 33.2 to 26.9% ($p = 0.0001$). However, there were significant differences across the two EDs (17.6% in site A and 34.8% in site B; $p = 0.0001$).

Clinical adoption of CDSSs: what are the barriers?

Despite the potential of CDSSs for enhancing evidence-based practice, reducing unnecessary imaging and improving patient safety, there are barriers to the implementation of CDSSs. Based on the experience of Drescher *et al.*, it appears that

time and convenience to access CDSSs is critical to end users [41]. Ip *et al.* have found that, in the implementation of CPOE, feature enhancements that optimize workflow are vital to adoption and meaningful use [45]. Kawamoto *et al.* noted that effective CDSSs should be computer based and provide automatic provision of decision support as part of the physicians workflow [46]. The success of a CDSS is dependent on a host of factors and may vary with the nature of the clinical problem [47,48]. Bates and co-authors offer 'ten commandments' for effective CDSSs: speed, anticipation of needs and delivery in real time, fitting the users' workflow, usability, recognition of physician resistance, altering rather than stopping behavior, simplicity, minimization of information requested, assessment of results with feedback and response, and monitoring and maintaining knowledge-based systems [49].

Practitioners are likely to ignore a CDSS unless it is concise, context specific and relevant to their current decision, delivered at the point of care. As noted by Lobach *et al.*, "provision of a recommendation, not just an assessment," "justification of decision support via provision of research evidence," and "promotion of action rather than inaction" are all important features associated with successful CDSS implementation [104]. The optimal form of evidence is peer-reviewed literature, such as those of decision-making rule and cost-effectiveness analysis. Practice guidelines, such as the American College of Radiology Appropriateness Criteria and the American Heart Association Cardiac Imaging Guidelines, may also be useful. Both the American College of Radiology and the American Heart Association devised imaging guidelines as a result of wide variation in practice, in the hope that such criteria would improve the value of imaging [50,51]. In addition, effective CDSSs must be easily translatable to context-specific actions. Vague reminders that are not specific to the clinical context are less likely to influence behavior.

In the experience of the authors, constant monitoring and modifications as needed are critical to ensure that the CDSS has the desired effects. Furthermore, organizational culture is vital to adopting technology in healthcare. Even the most well-designed CDSS delivery system will ultimately fail if attention is not paid to organizational processes and corporate culture. A culture emphasizing quality and safety, and a clearly stated vision from the highest levels of the organization are essential elements in the success of HIT.

CDSSs for medical imaging in the ED: more evidence is needed

The results of research investigating the impact of the CDSS on the utilization of CT imaging in the ED are promising. However, the strength of the evidence remains sparse so far. One reason for the lack of high-quality evidence may be that this type of research is at the crossroads of outcomes research, implementation research, systems redesign and medical informatics. Researchers specifically investigating the utility of CDSSs require a broad skillset that often goes beyond clinician researchers' traditional abilities. Another challenge is that research investigating CDSSs has to address the rapid pace at which HIT is progressing. Research that was relevant 5 years ago may be obsolete today because of advances in HIT. Investigators may therefore revert to the more easy to implement research strategies, such as observational or before- and after-study design.

Adoption rates of CDSSs in the community are unknown, but expected to be low. Financial barriers, physicians' resistance and concern about interoperability have been cited as potential obstacles to adoption [52]. Decreasing the number of imaging procedures may actually pose a financial disincentive for private, for-profit hospitals in a fee-for-service environment. However, it is the expectation that with the Health Information Technology for Economic and Clinical Health Act and the American Recovery and Reinvestment Act, a more widespread national adoption of HIT will ensue in the upcoming years; thus, some much-needed data on global impact of CDSSs will have to be generated.

Future perspective

Without doubt, the revolution of HIT will continue at a rapid pace. The opportunities for CDSSs in healthcare systems are tremendous. As more clinical practice guidelines and appropriateness criteria are developed, CDSSs will be increasingly relied upon to function as a tool in accelerating the adoption of such evidence into clinical practice. HIT holds one key to eliminating waste and improving quality, with a potentially large impact on decreasing unnecessary cost in healthcare. However, to fully realize the benefits of HIT, HIT developers will need to collaborate with clinician researchers to implement outcomes research showing the efficacy of CDSSs. As current research identifies barriers to implementation of CDSSs, further work is required to specifically address these concerns and find solutions. Clearly, CDSS development/upgrades are needed to improve user friendliness of HIT systems and provide better integration into the provider's workflow in the ED.

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Executive summary

Background

- Despite its vast utility, diagnostic medical imaging has been a culprit of rising healthcare expenditure. Health information technology, particularly clinical decision support systems, has been promoted as a means to address inappropriate diagnostic imaging and improve care delivery.

Findings

- Clinical decision support systems in the emergency department have the potential to promote more judicious use of medical imaging, thus decreasing cost and improving quality of healthcare delivery.

Conclusion

- More research is needed to understand how clinical decision support systems can impact the utilization of medical imaging in the emergency department.

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