MEDINFO 2015: eHealth-enabled Health
I.N. Sarkar et al. (Eds.)

doi:10.3233/978-1-61499-564-7-419

The Case for Conceptual and Computable Cross-Fertilization Between Audit and Feedback and Clinical Decision Support

Benjamin Brown[a,b], Niels Peek[a,b], Iain Buchan[a,b]

[a] *Health e-Research Centre, Farr Institute for Health Informatics Research, University of Manchester, UK*
[b] *Greater Manchester Primary Care Patient Safety Translational Research Centre, University of Manchester, UK*

Abstract

Many patients do not receive care consistent with best practice. Health informatics interventions often attempt to address this problem by comparing care provided to patients (e.g., from electronic health record data) to quality standards (e.g., described in clinical guidelines) and feeding this information back to clinicians. Traditionally these interventions are delivered at the patient-level as computerized clinical decision support (CDS) or at the population level as audit and feedback (A&F). Both CDS and A&F can improve care for patients but are variably effective; the challenge is to understand how the efficacy can be maximized. Although CDS and A&F are traditionally considered separate approaches, we argue that the systems share common mechanisms, and efficacy may be improved by cross-fertilizing relevant features and concepts. We draw on the Health Informatics and Implementation Science literature to argue that common mechanisms include functions typically associated with the other system, in addition to other features that may prove fruitful for further research.

Keywords:

Medical Audit; Quality Indicators; Healthcare Quality Improvement; Clinical Decision Support Systems.

Introduction

The prominence of evidence-based medicine has led to widespread acceptance of what consitutes good care. Implementing this evidence in clinical practice, however, is challenging – often referred to as the "second translational gap" Such problems lead to adverse outcomes for patients. For example, in the UK alone there are thought to be over 3,000 unnecessary strokes per year because patients with atrial fibrillation do not receive anticoagulant medication [1]. Barriers to implement evidence-based care may occur at different levels: individual patient-practitioner; provider team; provider organisation; and health system policy [2]. Health informatics interventions often attempt to address these barriers by highlighting to clinicians when patients may not receive care consistent with best practice evidence (e.g., in clinical guidelines) through analysis of patient data (e.g., from electronic health records [EHR]). When these interventions are delivered via computers during clinical encounters with patients, the interventions are called clinical decision support (CDS). When delivered outside clinical consultations and at the population-level, they are are typically described as audit and feedback (A&F). Systematic reviews of both types of intervention suggest they are moderately effective at ensuring patients receive improved care [3–5]. However, the reviews also suggest interventions are highly variable: sometimes the interventions work very well, and sometimes they do not [3–5]. The current challenge is therefore to understand how to maximize the efficacy. Although they are traditionally considered separate approaches, in this paper we suggest that computerized CDS and A&F share common mechanisms, and that their efficacy may consequently be improved by cross-fertilizing relevant features and concepts between each other.

To build our argument, we draw on literature from Health Informatics and from Implementation Science. Despite our focus on computer-based tools, we also draw on relevant evidence from non-computerized interventions. First we examine computerized CDS and A&F seperately: their functions, mechanisms and features associated with success. Next we consider their common aspects and provide a rationale for cross-fertilization. Finally, we provide examples of how this could be achieved both with functions typically associated with the other, in addition to other features that may improve their success. We end with a discussion on implications for future research and other tools that facilitate human interpretation of patient data.

Computerized Clinical Decision Support

CDS (both computerized and non-computerized) refers to a heterogeneous set of tools that can be broadly defined as "active knowledge systems which use two or more items of patient data to generate case-specific advice" [6]. This definition contrasts with passive knowledge systems, in which the user themselves must search the system [6]. Musen et al. classify CDS in three basic varieties [7]:

1. Patient-specific, situation-specific alerts, reminders, physician order sets, or other recommendations for direct action;
2. Information about the current clinical context to retrieve highly relevant online documents (e.g., *infobuttons*);
3. Organisation and presentation of information in a way that facilitates problem solving and decision making (e.g. graphical displays, documentation templates, structured reports).

We equate *computerized* CDS with the first variety. These are considered classic computerized CDS systems [7], and are arguably the most common [8,9]. Such systems provide custom-tailored assessments or advice based on patient-specific data (e.g., from EHRs or order entry systems) in consultation with a knowledge-base (usually best-practice evidence e.g. clinical guidelines), delivered via a computer to professionals at the point of care. Examples of these systems include [7,8]:

- Alerting clinicians if they are about to perform an action that may have adverse consequences (e.g., prescribing a macrolide antibiotic in a patient taking a statin);
- Reminding clinicians to perform a task (e.g., that a patient requires a cholesterol blood test);
- Suggesting management options for a particular patient based on their specific circumstances (e.g., suggesting changes in cholesterol-lowering treatment for a patient with high cholesterol).

Computerized CDS typically employs event-condition-action rules such as those in Arden syntax [7]. If a patient's data (the "event"; e.g., cholesterol level), meets criteria in accordance with the knowledge-base (the "condition"; e.g., >5mmol/L), then the CDS is trigerred (the "action"; e.g., suggestion of options for intensification of statin treatment). We exclude probabilistic CDS tools (e.g., Bayesian diagnostic systems) from our argument because they are usually not based on predefined clinical standards such as clinical practice gudelines.

We can surmise that computerized CDS attempts to improve compliance with best practice evidence by addressing barriers at the individual (patient-practitioner) level [2]. These include the health professional's lack of awareness or familiarity with the evidence, or their inertia of previous practice [10]. CDS works by making information available and visible to the health professional during the clinical encounter when action can be taken. However, CDS only works for patients that are encountered, and it is often ignored during time-pressured clinical encounters, or when a patient has an over-riding competing clinical priority. As a result, the efficacy of CDS is modest and highly variable. A recent Cochrane review of "on-screen, point of care computer reminders" demonstrated they improved processes of care by a median of 4.2% (interquartile range [IQR], 0.8% to 18.8%) [11]. Another review found only 58% of trials demonstrated an improvement in either processes of care or patient outcomes [3]. This review also demonstrated that CDS is more likely to be effective if it is delivered outside the EHR or order entry system, provides advice to patients as well as health professionals, and requires the user to articulate why they ignored a recommendation [3]. It has also been suggested that CDS may be variably effective because it does not target organisation-level barriers [12].

Audit & Feedback

A&F (both computerized and non-computerized) can be defined as "any summary of clinical performance of health care over a specified period of time" [13]. Other names for A&F include "clinical performance feedback," "performance measurement," and "quality measurement."

The audit part of A&F involves analysing data to produce a summary measure of clinical performance (interchangeably called a *quality indicator*, *performance measure*, or some combination of the two). Data may be obtained from medical records, computerized databases, or observations from patients [13]. Clinical performance is judged for a specified population according to accepted best practice (e.g., clinical guidelines). Quality indicators usually quantify clinical performance in a Donebedian classification as:

- Structural measures (e.g., number of nurses on a ward);
- Process measures (e.g.,proportion of eligible atrial fibrillation patients on anticoagulation); or
- Outcome measures (e.g., proportion of diabetic patients with good glycemic control (intermediate outcome) or number of myocardial infarctions per year per unit of population).

These indicators are generally calculated as proportions by comparing individual patients' data to the performance standard: the number of patients meeting the criteria form the numerator (e.g., number of children given a vaccination), and the total number eligible to meet the criteria form the denominator (e.g., number of children in the population eligible to receive the vaccine).

Feedback of audit results takes place after the clinical encounter, generally outside the clinical environment, and may target an individual, team or organisation. It may be delivered in a written, verbal or computerized format, and may include supporting materials, such as suggestions for improvement [5,13]. Feedback may also include *benchmarking* – comparison of recipients' performance with colleagues.

Traditionally, A&F was laboriously undertaken by the health professionals using paper medical records. However, widespread use of EHRs and web-based technologies means it is now much easier to undertake across multiple providers by external agencies such as governments or health service managers. As a result there is now an abundance of *computerized* A&F tools in healthcare systems around the world, variably termed *dashboards*, *benchmarking tools*, or *report cards*. Some are crude implementations of generic business intelligence software, others are more carefully developed for healthcare. These tools present information to health professionals (and often other audiences such as patients) via websites, computer applications or e-mail. Unlike non-computerized A&F, computerized A&F tools rarely make suggestions for improvement action to be taken by recipients.

Like CDS, A&F addresses barriers on the individual (patient-practitioner) level by making health professionals cognisant of their performance. As feedback is delivered outside the clinical encounter, it provides space and time for reflection and self-awareness, which ideally leads to behavior change. However, A&F also has the potential to address team and organisation-level barriers too, such as lack of resources and structural constraints [10] through the following ways:

- Feedback may be delivered to teams of clinicians and health care managers in addition to individual practitioners;
- Feedback provides recipients with a systematic and comprehensive view of entire patient populations served by a team or organisation, rather than only focusing on individual clinical encounters.

In addition to the space and time for reflection afforded by A&F, these factors encourage the formulation of service re-design plans for quality improvement. A limiting factor of A&F is that these plans must be formulated and undertaken, for which there must be sufficient time and resources. Consequently, like CDS, the efficacy of A&F is also modest and highly variable. The most recent Cochrane review of A&F demonstrated a median improvement in processes of care of 4.3% (IQR 0.5% to 16.0%) [5]. This review also demonstrated that A&F is more likely to be successful if the recipient is not performing well at baseline, and if feedback is provided by a supervisor or senior colleague, regularly, in multiple formats with clear targets and an action plan [5]. It has also been suggested that A&F may be more effective if it includes individual patient-level data (in addition to population summaries) [14–16], individual clinician-level data (in addition to team- or organisation-level) [16,17], and if it is provided in a timely manner [17,18].

Rationale for Cross-Fertilization

Although computerized CDS and A&F have traditionally been considered separate approaches to quality improvement, we argue the above evidence (summarized in Table 1) suggests they are in fact highly related for the following reasons:

1. **They use the same substrates**: Both interventions use EHR data and compare the observed clinical workflow against a clinical standard (e.g. guidelines).
2. **They use analogous analytic methods:** The number of event-condition-action rules triggered in computerized CDS systems for a specific patient population are equivalent to the numerator value of quality indicators in a computerized A&F system. The total number of patients for which the event-condition-action rules could be applied is equivalent to the denominator.
3. **They use similar methods to effect behavior change:** Both feed back to recipients assessments of observed care versus a clinical standard.

As described above, it is established that CDS and A&F are moderately effective at improving patient care. The current research challenge is to therefore understand how their efficacies can be maximized [3,19]. We argue that given their similarities, there is a need to explore potential, systematic cross-fertilization and learning between them. In the following section we present evidence that cross-fertilization of their associated functionalities could increase their associated effectiveness. We therefore argue that this relationship should be exploited in systematic, computable ways.

Suggestions for Cross-Fertilization in Practice

Evidence-based Synergies of Typical Functions

Computerized CDS is more effective if delivered seperately from the EHR or ordering system [3], and may also be improved if it targets team and organisation-level barriers [12]. Both these are features typically associated with A&F (Table 1). For example, a computerized CDS system may only remind a user to order an annual thyroid function blood test for someone on long-term thyroxine if their EHR is opened during a clinical encounter. However, this only works for patients that are seen, and the reminder may be ignored in a time-pressured clinical environment. If this system was delivered outside the EHR, it would be possible to see all the patients who needed the blood test (like A&F), which may provide the time and space to formulate a plan to ensure they all had the blood test. Furthermore, providing this more population-based information may also help address some of the team and organisation-level barriers (like A&F), such as understanding that additional services may be needed to facilitate all the patients receiving the blood test e.g. providing additional phlebotomy clinics or new phlebotomy staff.

Computerized A&F is more effective if provided in a timely manner [17,18], with suggested action plans [5], individual patient-level data [14–16] and individual clinician-level feedback [16,17]. These are features typically associated with CDS (Table 1). For example, a computerized A&F system normally only highlights the proportion of hypertensive patients who have uncontrolled blood pressure. This requires searching for the patients and formulating action plans to improve performance, for which there may not be the resources or skills. Computerized A&F may therefore be improved if the summary also provides individual-level data on which patients have uncontrolled blood pressure, in addition to suggestions for improvement action (like CDS). This may include individual patient actions such as choices for medication optimization, but also team and organisation-level changes such as introducing a home blood pressure monitoring service or installation of a blood pressure machine in the clinic waiting room. Some computerized CDS systems already have similar functions to this termed “population registries”, however they are uncommon in practice [8] and only provide suggestions for individual patient actions. Furthermore, to address barriers at the individual patient-practitioner level, such as health professional’s lack of awareness or familiarity with clinical guidelines, requires knowledge of which clinicians need targeting. This is facilitated if feedback reports specify individual clinician performance in addition to their team or organisation (like CDS). This may also be more effective if provided close to the time of the clinical encounter (like CDS), when the experience is fresh in the clinician’s mind and the patient’s care is amenable to action, for example they have not left the hospital or moved address.

Conceptual Extension to Synergies of Other Functions

The evidence above suggests that functions typically associated with A&F are likely to improve the efficacy of computerized CDS, and vice versa, which re-inforces our argument that the two interventions are related. It also suggests that cross-fertilization of other features, for which there may not currently be supporting evidence, may be worth investigating. For example, computerized CDS may be more successful if it also provided population-level summaries like A&F *during* clinical encounters. One may hypothesize that when a computerized CDS system is triggered (e.g. for raised cholesterol), knowing the proportion of the eligible population for whom the alert would also fire (e.g. proprtion of patients with high cholesterol) will put the information in a broader context of clinical performance, re-inforcing the alert’s importance. This may more effectively motivate the recipient to take action, reducing alert fatigue [20].

This principle may also extend to other features that are not necessarily considered typical of either CDS or A&F, but that have been shown to improve their efficacy (Table 1). For example, computerized CDS is more effective if it provides advice for patients and if it requires a reason for over-riding its advice [3]. To our knowledge these features have not been investigated extensively in computerized A&F, though may improve its efficacy: providing advice to patients may improve adherence to medication and engagement with healthcare in the same way as CDS; and requiring users to justify why feedback is ignored may improve cognitive engagement with the quality improvement process. We suggest these and other areas in Table 1 may prove fruitful areas for further research.

We acknowledge there may be other features of computerized CDS and A&F interventions that are associated with improved efficacy, which have not been mentioned above. This may include features for which there are currently conflicting opinions or evidence, such as the use of benchmarking in A&F [15,19,21,22], or other features not yet discovered. The application of behavioural change theory and use of qualitative evaluations in future research may help identify these additional features. This idea is beginning to gain traction in the A&F literature [19,22], but to our knowledge has not yet been mirrored in the CDS literature. We suggest that when new theories or features are discovered for either computerized CDS or A&F, they should be inclusively applied to both and their influence on efficacy assessed.

Table 1 – Comparison of computerized CDS and A&F

Feature	CDS	A&F
Data source	EHR	EHR
Analytic method	Event-condition-action rules	Quality indicators
Unit of analysis	Individual patient	Population
Delivery	During clinical encounter	Outside/after clinical encounter
Users	Individual clinicians	Individual clinicians, teams, organisations
Recommends improvement actions	Yes	No
Features associated with success	Delivered outside EHR Providing advice to patients Requiring over-ride reasons Targeting organisation-level barriers	Low baseline performance of recipient Feedback provided by supervisor/senior Regular feedback Multiple formats of feedback Clear targets and action plans fed back Individual level information (patient and clinician) Timely information

Discussion

We have studied the features of computerized CDS and A&F and argued that they they should be considered as related, rather than separate, approaches to healthcare quality improvement. In doing so, we have suggested their efficacy may be improved through the cross-fertilization of features typically associated with the other, and that future research should explore linking the two in a computable synergy.

Previous attempts to increase the understanding of (the effectiveness of) CDS and A&F have largely been limited to bottom-up aggregation of empirical evidence concerning a hetereogeneous set of intervention studies, with little success to date. Our approach advocates consideration of the mechanisms that underpin how they work and what they are trying to achieve, which we think will be more successful.

Our argument is not that computerized CDS and A&F should be used as 'multifacted' or 'co-' interventions; these terms suggest separate tools glued together. Our vision is that given their similarities these interventions should seamlessly incorporate successful features and other learning from each other. Interestingly, in support of this assertion, merely adding reminders to A&F has not been shown to impact efficacy [5], nor adding summary feedback to CDS [3], and there is little support from systematic reviews for multifaceted over single-component interventions in general [23]. Furthermore, we do not advocate that the empirical evidence relating to computerized CDS and A&F be simply combined to increase the power of meta-regressions in systematic reviews, as this belies the clear differences between them. Our argument is rather that a shared conceptualization can strengthen the generation and testing of specific hypotheses that draw on their shared mechanisms. We believe our understanding of both interventions can be advanced by considering the empirical evidence across them and borrowing evidential strength from adjacent areas where appropriate.

In addition to improving the efficacy of both computerized CDS and A&F, there are corollary benefits to their cross-fertilization. For example, the cross-fertilization encourages the development of common technical standards, which promises to save implementation time and effort [24]. Linking quality indicators to possible improvement actions also provides a more accurate measure of care quality, which is important if used for accountability purposes (e.g., performance-based payment). For example, it is more accurate to know the proportion of uncontrolled hypertensive patients prescribed suboptimal medication, rather than simply the proportion of uncontrolled hypertensives.

Although we have limited our discussion to CDS and A&F, our argument may well extend to a broader set of computerized interventions that facilitate clinician interpretation of patient data. Examples include range checks for laboratory test results, electronic checklists, and risk prediction tools. And although we excluded probablistic CDS systems from our discussion, they may also be relevant. For example there are arguments for the application of risk prediction tools in A&F [14] and a need for actionable suggestions (like CDS) in risk prediction [25]. Furthermore, there may be implications for non-computerized interventions too, as there are suggestions that A&F is most effective when there is external facilitation [26], which may be considered an 'educational outreach' feature [13].

A limitation of our argument is that the argument has occasionally drawn on evidence from non-computerized CDS and A&F, in addition to their computerized counterparts. This was necessary because some of the literature (particularly regarding A&F) does not distinguish between these two modes of delivery [5,6]. We believe our assertions transcend the distinction between computerized and non-computerized versions of these tools. Nevertheless, future research should empirically test whether our hypotheses regarding cross-fertilization hold in solely computerized settings. Our group has already started to do this by developing experimental computerized interventions [27,28].

Conclusion

We argue that computerized CDS and A&F systems are not separate but highly related approaches to quality improvement. We suggest that cross-fertilization of features and learning betweem them may improve their efficacy. We have provided examples of how this may be achieved in computable ways, along with suggestions for future research.

Acknowledgments

Supported by the Wellcome Trust [104438/Z/14/Z] and UK Medical Research Council [MR/K006665/1].

References

[1] Cowan C, Healicon R, Robson I, et al. The use of anticoagulants in the management of atrial fibrillation among general practices in England. Heart 2013; 99(16):1166–72.

[2] Ferlie E, Shortel S. Improving the Quality of Health Care in the United Kingdom and the United States: A Framework for Change. Milbank Q. 2000;79(2):281–315.

[3] Roshanov PS, Fernandes N, Wilczynski JM, et al. Features of effective computerised clinical decision support systems: meta-regression of 162 randomised trials. BMJ 2013;346:f657.

[4] Shojania KG, Jennings A, Mayhew A, Ramsay C, Eccles M, Grimshaw J. Effect of point-of-care computer reminders on physician behaviour: a systematic review. CMAJ 2010;182(5):E216–25.

[5] Ivers N, Jamtvedt G, Flottorp S, et al. Audit and feedback: effects on professional practice and healthcare outcomes. Cochrane Database Syst Rev. 2012;(6).

[6] Wyatt J, Spiegelhalter D. Field trials of medical decision-aids: potential problems and solutions. Proc Annu Symp Comput Appl Med Care. 1991;3–7.

[7] Musen MA, Middleton B, Greenes RA. Clinical Decision-Support Systems. In: Shortliffe EH, Cimino JJ, editors. Biomedical Informatics: Computer Applications in Health Care and Biomedicine. 4th ed. London: Springer-Verlag; 2014. p. 643–74.

[8] Wright A, Sittig DF, Ash JS, et al. Development and evaluation of a comprehensive clinical decision support taxonomy: comparison of front-end tools in commercial and internally developed electronic health record systems. J Am Med Inform Assoc 2011;18(3):232–42.

[9] Bright TJ, Wong A, Dhurjati R, et al. Effect of clinical decision-support systems: a systematic review. Ann Intern Med 2012;157(1):29–43.

[10] Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH. Why Don't Physicians Follow Clinical Practice Guidelines. JAMA. 1999; 282(15):1458-65.

[11] Shojania K, Jennings A, Mayhew A, Ramsay C, Eccles M, Grimshaw J. The effects of on-screen, point of care computer reminders on processes and outcomes of care. Cochrane Database Syst Rev. 2009;(3).

[12] Goud R, van Engen-Verheul M, de Keizer NF, et al. The effect of computerized decision support on barriers to guideline implementation: a qualitative study in outpatient cardiac rehabilitation. Int J Med Inform 2010;79(6):430–7.

[13] Cochrane Effective Practice and Organisation of Care Group (EPOC). Data Collection Checklist. 2002.

[14] Ivers N, Barnsley J, Upshur R, et al. My approach to this job is one person at a time. Can Fam Physician. 2014;60:258–66.

[15] Søndergaard J, Andersen M, Kragstrup J, et al. Why has postal prescriber feedback no substantial impact on general practitioners' prescribing practice? A qualitative study. Eur J Clin Pharmacol 2002;58(2):133–6.

[16] Cresswell KM, Sadler S, Rodgers S, et al. An embedded longitudinal multi-faceted qualitative evaluation of a complex cluster randomized controlled trial aiming to reduce clinically important errors in medicines management in general practice. Trials 2012;13(1):78.

[17] Hysong SJ, Best RG, Pugh J. Audit and feedback and clinical practice guideline adherence: making feedback actionable. Implement Sci 2006;1:9.

[18] Bradley EH, Holmboe ES, Mattera JA, Roumanis SA, Radford MJ, Krumholz HM. Data feedback efforts in quality improvement: lessons learned from US hospitals. Qual Saf Heal Care 2004;13:26–32.

[19] Ivers NM, Sales A, Colquhoun H, et al. No more "business as usual" with audit and feedback interventions: towards an agenda for a reinvigorated intervention. Implement Sci 2014;9:14.

[20] Kesselheim AS, Cresswell K, Phansalkar S, et al. Clinical decision support systems could be modified to reduce "alert fatigue" while still minimizing the risk of litigation. Health Aff 2011;30(12):2310–7.

[21] Kiefe CI, Allison JJ, Williams OD, et al. Improving quality improvement using achievable benchmarks for physician feedback: a randomized controlled trial. JAMA 2001;285(22):2871–9.

[22] Brehaut JC, Eva KW. Building theories of knowledge translation interventions: use the entire menu of constructs. Implement Sci 2012;7(1):114.

[23] Squires JE, Sullivan K, Eccles MP, et al. Are multifaceted interventions more effective than single-component interventions in changing health-care professionals' behaviours? An overview of systematic reviews. Implement Sci 2014;9(1):152.

[24] Kukhareva P, Kawamoto K, Shields DE, et al. Clinical Decision Support-based Quality Measurement (CDS-QM) Framework: Prototype Implementation, Evaluation, and Future Directions. AMIA Annu Symp Proc (In press).

[25] Lewis GH. "Impactibility Models": Identifying the Subgroup of High-Risk Patients Most Amenable to Hospital-Avoidance Programs. Milbank Q 2010;88(2):240–55.

[26] Cannell PJ. Evaluation of the end user (dentist) experience of undertaking clinical audit in a PCT-led NHS Modernisation Agency pilot scheme. Prim Dent Care 2009;16(4):168–76.

[27] Brown B, Williams R, Sperrin M, et al. Making Audit Actionable: An Example Algorithm for Blood Pressure Management in Chronic Kidney Disease. AMIA Annu Symp Proc (In press).

[28] Van Engen-Verheul M, de Keizer N, van der Veer S, et al. Evaluating the effect of a web-based quality improvement system with feedback and outreach visits on guideline concordance in the field of cardiac rehabilitation: Rationale and study protocol. Implement Sci (In press).

Address for correspondence

Benjamin Brown, Health e-Research Centre, Farr Institute for Health Informatics Research, The University of Manchester, Vaughan House, Portsmouth Street, Manchester, M13 9PL, UK. benjamin.brown@manchester.ac.uk