

## Systematic review

# What to expect from electronic patient record system implementation: lessons learned from published evidence

Cite this article: Priestman W, Sridharan S, Vigne H, Collins R, Seamer L, Sebire NJ. What to expect from electronic patient record system implementation: lessons learned from published evidence. *J Innov Health Inform.* 2018;25(2):92–104.

<http://dx.doi.org/10.14236/jhi.v25i2.1007>

Copyright © 2018 The Author(s). Published by BCS, The Chartered Institute for IT under Creative Commons license <http://creativecommons.org/licenses/by/4.0/>

### Author address for correspondence:

Neil J. Sebire  
Histopathology Department  
Level 3 Camelia Botnar Laboratories  
Great Ormond Street Hospital  
London WC1N 3JH, UK  
Email: [neil.sebire@gosh.nhs.uk](mailto:neil.sebire@gosh.nhs.uk)

Accepted May 2018

### Ward Priestman

ICT Department, Great Ormond Street Hospital, UK

### Shankar Sridharan

ICT Department, Great Ormond Street Hospital, UK

### Helen Vigne

ICT Department, Great Ormond Street Hospital, UK

### Richard Collins

ICT Department, Great Ormond Street Hospital, UK

### Loretta Seamer

Finance Department, Great Ormond Street Hospital, UK

### Neil J. Sebire

ICT Department, Great Ormond Street Hospital, UK

## ABSTRACT

**Background** Numerous studies have examined factors related to success, failure and implications of electronic patient record (EPR) system implementations, but usually limited to specific aspects.

**Objective** To review the published peer-reviewed literature and present findings regarding factors important in relation to successful EPR implementations and likely impact on subsequent clinical activity.

**Method** Literature review.

**Results** Three hundred and twelve potential articles were identified on initial search, of which 117 were relevant and included in the review. Several factors were related to implementation success, such as good leadership and management, infrastructure support, staff training and focus on workflows and usability. In general, EPR implementation is associated with improvements in documentation and screening performance and reduced prescribing errors, whereas there are minimal available data in other areas such as effects on clinical patient outcomes. The peer-reviewed literature appears to under-represent a range of technical factors important for EPR implementations, such as data migration from existing systems and impact of organisational readiness.

**Conclusion** The findings presented here represent the synthesis of data from peer-reviewed literature in the field and should be of value to provide the evidence-base for organisations considering how best to implement an EPR system.

**Keywords:** electronic patient record, information technology, implementation lessons, benefits, barriers

## INTRODUCTION

Great Ormond Street Hospital (GOSH) and the associated University College London Institute of Child Health represent a large specialist, research active tertiary Children's Hospital in London. As a component of its digital strategy, GOSH underwent a procurement process for a comprehensive electronic patient record/electronic health record (EPR/EHR) system. In parallel to the core clinical EPR system procurement, a similar process was synchronously used to procure a research and analytics platform.

As a part of the process, previous peer-reviewed scientific publications regarding implementation of EPR systems were reviewed to determine which factors have been positively and negatively associated with successful implementations, and to derive data from which to base expectations for clinical activity during and following implementation.

## METHODS

A literature search was performed of PubMed (all years to June 2017) using the search terms 'electronic [ti] AND record \* [ti] AND (procurement [ti] OR implement \* [ti])'. The search was restricted to articles published in English. This was not a formal systematic review but rather a review to provide a pragmatic, useful overview of previous findings in relation to EPR implementation in health care settings to inform practice.

## RESULTS

Three hundred and twelve articles were identified in the initial search, of which 117 included findings relevant to purpose, presented below, categorised by area.

### Overview

Early publications regarding EPR implementations provided simple descriptions without qualitative/quantitative data,<sup>1</sup> although critical appraisals of specific examples have provided 'lessons learned'.<sup>2</sup>

In general, implementing comprehensive EPR systems requires many strategic decisions around aspects such as programme scale, integration/replacement of existing systems, timing of implementation in clinical areas (phased versus 'big-bang'/enterprise-wide), the development of workflows/clinical pathways and order sets and planning regarding staff engagement. Most hospitals have departments in different stages of digitisation, some requiring integration, others paper based. Planning is also required to ensure supporting hospital infrastructures, such as wired/wireless networks, servers and cybersecurity, which are adequate for EPR requirements before implementation,<sup>3</sup> and principles of project management should be followed.<sup>4</sup>

Studies have identified several investment areas for EPR projects beyond technical infrastructure (hardware/software), including staff (communication, engagement and training), estates/facilities (space requirements) and operational issues (institution specific aspects and clinical workflow management).

Such costs vary widely according to scope and size of organisational activities and baseline infrastructure, estates and staffing.<sup>5</sup>

In general, staff will have preconceived expectations for EPR systems regarding usability, support/training, communication, patient interaction and collaboration.<sup>6</sup> Main themes associated with EPR implementations also consistently include cost/resource, risk assessment, governance, customisation, clinical workflows, usability and training, and for most areas, there is a significant discordance between evidence and staff expectations.<sup>7</sup>

EPR implementations should drive clinical and operational changes, including improvement in clinical processes.<sup>8</sup> In one study, surgical clinic design, patient scheduling, physical space layout, staffing and workflows were all improved as a part of the 'EPR implementation' process.<sup>9</sup>

Chief Information Officers (CIOs) from English National Health Service trusts reported the expected benefits of EPR implementations to include efficiency, availability/accessibility of clinical information and patient safety; challenges were consistently around clinician engagement and inadequate resource (financial and human).<sup>10</sup> These are similar to USA CIOs, where physician cooperation was a major issue, in addition to maintenance and upgrades.<sup>11</sup>

Moving to an EPR system that represents significant organisational change is analogous to grieving, with staff experiencing loss, denial, anger, bargaining, depression and finally acceptance, many of which can be minimised by managing expectations through communication.<sup>12</sup> It should also be recognised that the EPR implementation should provide a sustainable platform for ongoing development rather than a single event. (e.g., cross-platform/vendor mechanisms for bidirectional EPR data exchange and application development).<sup>13</sup>

There are limited data regarding EPR implementation effects on other specific services. One study examined help desk support, reporting increased call volume during go-live, which returned to baseline, with further increases during unplanned EPR downtime.<sup>14</sup>

### Barriers to success

Several studies have identified barriers to successful EPR implementations (Table 1). Initially, difficulties were technical (integration, security and purchase cost),<sup>15</sup> but subsequently barriers were predominantly operational and behavioural, including physician engagement, workflow and cost of maintenance/upgrades. Indeed, several studies report major issues surrounding workflow changes when moving from paper-based systems.<sup>8,11,16</sup>

Organisational leadership and clarity of communication are vital, and staff must understand the significant changes in working practices associated with the EPR implementation. Unfamiliarity with new systems may be interpreted negatively and addressing such staff concerns can avoid subsequent difficulties.<sup>17</sup> End users may not feel engaged with the decision to implement or choose an EPR system<sup>18</sup> and usability issues (design, configuration and implementation) will increase clinical staff resistance, worsened if staff are not made aware that productivity may initially fall post-go-live. Workflow evaluation

**Table 1 Summary of main findings from studies reporting on barriers to successful EPR implementation**

Study	Year	Barriers
Scantlebury <i>et al.</i> <sup>28</sup>	2017	Poor staff understanding of rationale and benefits
		Poor system integration
		Parallel paper systems
Chan <i>et al.</i> <sup>11</sup>	2016	Physician cooperation
		Costs of maintenance and upgrades
		Workflow changes
Harle <i>et al.</i> <sup>27</sup>	2016	Lack of recognition of clinical benefit
Chan <i>et al.</i> <sup>11</sup>	2016	Obtaining physician cooperation
		Costs of maintenance and upgrades
McAlearney <i>et al.</i> <sup>12</sup>	2015	Workflow and practice changes
		Shifts in expertise
		Patient interaction changes
Clarke <i>et al.</i> <sup>10</sup>	2015	Training and education issues
		Ensuring adequate clinician involvement limited financial and human resources
McAlearney <i>et al.</i> <sup>12</sup>	2013	Poor staff IT skills
		Resistance to workflow changes
Terry <i>et al.</i> <sup>22</sup>	2012	Poor staff training for system use
		Inadequate interoperability
Cresswell <i>et al.</i> <sup>18</sup>	2011	Poor user consultation
		Inadequate customisation
McAlearney <i>et al.</i> <sup>16</sup>	2010	Resources
		Ongoing system support
		User interface
Jensen <i>et al.</i> <sup>25</sup>	2009	Regulatory compliance
Samoutis <i>et al.</i> <sup>20</sup>	2007	Data reliability
Wibe <i>et al.</i> <sup>21</sup>	2006	Staff ability to use technology
Crosson <i>et al.</i> <sup>17</sup>	2005	Staff training resource
Scott <i>et al.</i> <sup>19</sup>	2005	Poor communication
Retchin <i>et al.</i> <sup>15</sup>	1999	Poor usability
		Lack of integration, security issues, providers who were inflexible and prohibitive purchase cost

itself may be traumatic, since staff roles or reporting structures may change. Leadership should address such issues early, consensus building in areas such as adoption, but with decisive leadership to resolve ongoing issues.<sup>19,20</sup>

General barriers include lack of sufficient resource for staff participation and training and the lack of senior staff involvement, such as chief nurses.<sup>20–22</sup> Behavioural barriers are consistently reported, especially persuading staff to change work practices,<sup>23</sup> with poor computer skills increasing resistance to change.<sup>24</sup> Usability should therefore be optimised<sup>25</sup> and issues regarding EPR supporting compliance with mandatory reporting should be addressed early.<sup>16</sup>

Despite these issues, in general, staff and patients are supportive of EPR systems.<sup>20</sup> Staff initially worry about changes in clinical practice, threats to professionalism, shifts in expertise, changes in patient interactions, impact on clinical training and effects on patient care,<sup>26</sup> without being aware of potential benefits.<sup>27</sup> There is generally poor staff understanding of rationale for EPR implementation, whereas their participation is related to the amount of training and support and understanding of benefits. Allowing parallel use of paper or legacy systems should be avoided.<sup>28</sup>

**Factors associated with successful EPR implementation**

Major success factors include strong organisational support with a visible executive team,<sup>29</sup> and well-communicated aims for clinical processes and workflows (Table 2).<sup>8</sup> Whilst

**Table 2 Factors associated with successful EPR implementations**

Study	Year	Success factors
Gross <i>et al.</i> <sup>35</sup>	2016	Identify and address gaps in system functionality early
		Consider aspects such as communication mechanisms, in addition to 'core' EPR functions
Joukes <i>et al.</i> <sup>6</sup>	2015	Focus on usability
		Alignment with work processes
Cucciniello <i>et al.</i> <sup>34</sup>	2015	Support and training (ongoing)
		Use of patient data
McAlearney <i>et al.</i> <sup>24</sup>	2013	Improving general IT skills
		Overt commitment across the whole organisation
Craven <i>et al.</i> <sup>44</sup>	2013	Development and resourcing of new roles
		Investment in mechanisms to assess ongoing impact
Laramee <i>et al.</i> <sup>39</sup>	2011	Ongoing optimisation
		Investment initially in correct system selection
Corrao <i>et al.</i> <sup>37</sup>	2010	Ensuring adequate hardware and technology
		Optimise workflows
McAlearney <i>et al.</i> <sup>43</sup>	2010	Focus on staff training as customers
		Early detection of usability issues
Fullerton <i>et al.</i> <sup>36</sup>	2006	Focus on continuous customisation and improvement
		Demonstrate data use for quality improvement
Badger <i>et al.</i> <sup>38</sup>	2005	Extensive staff involvement in system choice and implementation
		Investment in technical and training support at go-live
Souther <i>et al.</i> <sup>29</sup>	2001	Extensive training
		Champions from all disciplines
		Organisation support
		Executive visibility

several generic factors facilitate success, such as project management, procurement and implementation strategies.<sup>30</sup> EPR-specific issues include early focus on system migration, ensuring adequate infrastructure, support and training and demonstration of efficiency.<sup>31</sup> Securing adequate information technology (IT) resources from the beginning of the programme is also essential.<sup>32</sup> Formal evaluation of organisational readiness for EPR implementation, in terms of culture, leadership, management, technical infrastructure, governance and operational planning improves the chances of success.<sup>33</sup> Recognition that EPR will require resourcing of new roles, in addition to investment in mechanisms to assess post-implementation impact are important.<sup>34</sup> Finally, there must be understanding of potential gaps in capability system functionality and awareness of important 'peripheral' effects, such as impacts on communication.<sup>35</sup>

Other success factors include obtaining representation from all user types, from procurement through implementation, to improve engagement, decisions, customization and workflow planning.<sup>36</sup> Early evaluation of usability issues allows customisation before go-live, improving user satisfaction.<sup>37</sup>

A consistent factor reported is technical support and training during implementation,<sup>36</sup> including hands-on training with staff (super users), such as doctors, nurses, administrators and IT staff.<sup>38,39</sup> This training should be 'role-specific', for example, nurses supporting nurses.<sup>40</sup> Furthermore, training will be required on an ongoing basis, for new staff, system upgrades and revisions.<sup>6,32,41</sup>

Infrastructure/network frustrations, poor user interfaces and unrealistic IT competence expectations are reported as factors requiring early attention, including a focus on IT literacy prior to EPR implementation.<sup>42</sup> Successful implementations emphasise ongoing optimisation and improvement, rather than just deployment, and demonstrate to users the system value.<sup>24,43</sup>

Investment of time during procurement for system selection and technology hardware requirements, along with optimising workflows are all associated with successful implementations,<sup>44</sup> with workflow optimisation in particular being a major ongoing component.<sup>32,45</sup> Whilst initial emphasis is ensuring safe EPR functionality, this should evolve towards user customisation and secondary use of data to improve outcomes, such as patient safety.<sup>46</sup> Successful sites demonstrate common themes, including the use of published evidence, focus on workflows rather than technology and ensuring that management structures facilitate the process.<sup>47</sup> Specifically, regarding academic medical centres, early and ongoing executive support, emphasis on training and support, ongoing system optimisation and patient portal functionality were success factors.<sup>48</sup>

### Staff evaluation of EPR implementations

Distinct from the evaluation of organisational barriers and facilitators, several studies have examined staff views following the EPR implementation, providing information regarding satisfaction. In general, doctors report that patient care with EPR is better than previously, particularly regarding

the quality of medical documentation.<sup>49</sup> There is of course marked variation across clinicians from 'disappointment' to 'tremendous', highlighting need for expectation management and staff preparation.<sup>50</sup> Overall physician acceptance of EPR is high, with 90% of junior medical staff preferring EPR over paper records; junior staff generally show greater approval ratings than consultants, likely representing age-effect in relation to acceptance of change and uptake of technology.<sup>51</sup>

Medical staff may have reservations about potential negative effects on the quality of care and patient interactions and also concerns regarding their own competency in EPR use, although most of these no longer exist once benefits are recognised.<sup>52</sup> Most physicians do, however, feel that EPR use requires more of their time, albeit associated with improved documentation, but suggesting that this results in reduced teaching time for juniors.<sup>53,54</sup>

Overall, doctors' satisfaction with systems is associated with the adequacy of training and support and system usefulness for their specific practice.<sup>55</sup> In general, staff who were described as innovative were much less likely to view EPR implementation as difficult.<sup>56</sup>

Clinicians often initially feel that EPR is time-consuming, particularly if inadequate hands-on training/support is provided.<sup>57</sup> Despite this, most agree that EPR use improves billing and quality, with those using comprehensive systems more likely to report positive effects.<sup>58</sup> Doctors generally adapt to the workflow changes required and recognise benefits such as decreased time out of the examination room.<sup>59</sup> For example, whilst there were initial concerns about impact on patient interaction by ophthalmologists, there was no actual effect on clinic efficiency or satisfaction.<sup>60</sup>

Broadly, older clinicians tend to have worse opinions of EPR,<sup>61</sup> and a trend for older medical staff to leave or retire around EPR implementation is reported.<sup>62</sup> However, most clinicians refuse to return to handwritten records.<sup>63</sup> The apparent increased clinician time required to operate EPRs should be addressed early.<sup>64</sup>

Several studies have evaluated nursing views and report that nurses are largely positive, EPR being associated with improved documentation, increased satisfaction, drug information accuracy and patient safety.<sup>65,66</sup> The main challenges are around the documentation processes and difficulties in interdisciplinary communication<sup>67</sup>; face-to-face communication between nurses and doctors may be significantly reduced post-EPR implementation.<sup>68</sup> It is therefore important that senior nurses are involved early to reduce these effects and encourage uptake.<sup>69</sup>

Few studies have examined effects directly on patients, but in general, EPR implementation does not affect patient satisfaction,<sup>70</sup> with no improvements in waiting time.<sup>71</sup> However, the use of patient portals is associated with patients feeling more prepared for their appointments,<sup>72</sup> and the availability of health information was considered valuable.<sup>73</sup>

### Productivity effects

Numerous studies have evaluated the effects of EPR systems on efficiency/productivity (Table 3). Short-term

**Table 3 Studies reporting on efficiency and productivity pre- and post-EPR implementation**

Study	Year	Main findings
Yadav <i>et al.</i> <sup>77</sup>	2017	More documentation errors overall Improved physical finding documentation
Akenroye <i>et al.</i> <sup>117</sup>	2017	No effect on hypertension or obesity rates
Haidar <i>et al.</i> <sup>88</sup>	2017	Reduced physician productivity in outpatients
Riahi <i>et al.</i> <sup>100</sup>	2017	Overall significant cost savings due to reduced medication errors, better implementation of clinical practice guidelines, improved infection prevention and cost-effective diagnostic testing.
McDowell <i>et al.</i> <sup>89</sup>	2017	Operating theatres increase in patient turnaround time of around 20% post-implementation, which returned to baseline by 6 months
Caryon <i>et al.</i> <sup>107</sup>	2017	Reduced ITU medication errors
Rupp <i>et al.</i> <sup>86</sup>	2017	Emergency department, sustained increase in length of patient stay until around 1 year later.
Dean <i>et al.</i> <sup>96</sup>	2016	Improved quality of discharge summaries
Han <i>et al.</i> <sup>93</sup>	2016	Reduced severe medication errors and ICU mortality
Finn <i>et al.</i> <sup>106</sup>	2016	Improved detection of prescribing errors
Raval <i>et al.</i> <sup>105</sup>	2015	Reduced clerical errors, work hours saved annually by EPR-based handovers.
Wormer <i>et al.</i> <sup>76</sup>	2015	Significant increase (approximate doubling) in average time spent by junior staff documenting in the first 6 months post-EPR implementation, which improves over time but remains greater than baseline
Singh <i>et al.</i> <sup>87</sup>	2015	No effect on efficiency
Flatow <i>et al.</i> <sup>92</sup>	2015	Reduced ICU mortality
Ward <i>et al.</i> <sup>82</sup>	2014	Transient increased length of stay until 8 weeks Increased laboratory testing and imaging
Ward <i>et al.</i> <sup>83</sup>	2014	No effect on emergency room length of stay
Reddy <i>et al.</i> <sup>84</sup>	2014	No effect on outpatient volume
Patterson <i>et al.</i> <sup>85</sup>	2014	No effect on readmission rates (cardiac)
Hye <i>et al.</i> <sup>116</sup>	2014	Increase in aortic aneurysm screening rates
Gascon <i>et al.</i> <sup>104</sup>	2013	Laboratory medicine, reduced errors, improved turnaround times, integration into record
McGuire <i>et al.</i> <sup>113</sup>	2013	Improved ability to provide care more safely.
Wang <i>et al.</i> <sup>114</sup>	2013	Increased appropriate antithrombotic therapy, blood pressure control, HbA1c testing and smoking cessation intervention.
Reed <i>et al.</i> <sup>115</sup>	2013	Reduced emergency visits in patients with diabetes mellitus
Gascon <i>et al.</i> <sup>104</sup>	2013	Improved laboratory processes (better patient identification, less labelling or requesting errors and shorter response times)
Kritz <i>et al.</i> <sup>108</sup>	2012	Improved annual assessment performance
Spellman <i>et al.</i> <sup>81</sup>	2012	Transient increased emergency department length of stay and time to see doctor, resolved by 3 months
Herrin <i>et al.</i> <sup>112</sup>	2012	Patients with diabetes more likely to receive optimal care Increased antimicrobial recommendations
Cook <i>et al.</i> <sup>103</sup>	2011	Reduced antibiotic use Reduced nosocomial infections.
Albuquerque <i>et al.</i> <sup>95</sup>	2011	Reduced physician calls to treatment units
Harshberger <i>et al.</i> <sup>109</sup>	2011	Improved quality of data collection
Gunnigberg <i>et al.</i> <sup>110,111</sup>	2008, 2009	Post-EPR improvement in recording of pressure ulcers.
Verwey <i>et al.</i> <sup>79</sup>	2008	No time efficiency savings
Grieger <i>et al.</i> <sup>97</sup>	2007	Improved billing accuracy and cost recovery
Rosenbloom <i>et al.</i> <sup>94</sup>	2006	Improved documentation of weight and height (growth charts)
Evans <i>et al.</i> <sup>98</sup>	2006	5% productivity increases per annum
Pizziferri <i>et al.</i> <sup>78</sup>	2005	No difference in overall time per patient in clinic
Keshavgee <i>et al.</i> <sup>75</sup>	2001	Increased clinician time required for documentation Returns to baseline by 18 months post-go-live

implementation impact must be distinguished from long-term effects, although most studies have focused on the immediate post-implementation period.

EPR implementation is associated with the increased clinician time entering data.<sup>74</sup> In one study, staff time spent 'documenting' increased initially by 50%, returning to baseline by

18 months; (partly due to drop-out of physicians who found EPR difficult).<sup>75</sup> Another study reported approximate doubling of average time spent by junior staff documenting in the 6-months post-EPR implementation, which improved but remained greater than baseline.<sup>76</sup> In a pre-/post-study of EPR, rates of inaccurate documentation were significantly higher compared to paper charts, but expected physical examination findings were more frequently recorded. However, inaccuracy rates were significantly lower for junior staff compared to consultants, suggesting 'user' rather than 'system' factors.<sup>77</sup>

In a study evaluating outpatients, post-implementation, overall time per patient was not significantly different, although users felt that documentation took longer.<sup>78</sup> Another study also reported no time efficiency post-EPR,<sup>79</sup> whilst another study reported average total time per patient as significantly longer.<sup>80</sup> Clinical impact, however, depends on the setting. In the study of emergency department activity, the overall length of stay and time to see a doctor increased during EHR implementation by 5%–20% but returned to baseline within 3 months.<sup>81</sup> Another emergency department study reported that average length of stay increased and patient satisfaction reduced transiently, returning to baseline by 8 weeks. However, laboratory testing, medication administration and radiologic imaging all showed sustained increase post-implementation.<sup>82</sup> In a further study, no difference was found in measures of operational performance,<sup>83</sup> and others also report no effect on outpatient volumes<sup>84</sup> or readmission rates.<sup>85</sup> The most recent emergency department study reported no differences in volume, admissions, or transfers but increased length of stay until 1 year later.<sup>86</sup>

In a pre-/post-implementation study in a specialist eye hospital, there was no significant change in patient volume or diagnostic tests usage,<sup>87</sup> whereas a similar study in an emergency department reported increased patient processing time, which improved to better than baseline over 10 months. In an outpatient study, physician productivity initially decreased by 20%, but with the corresponding reduced time spent post-clinic reviewing documentation.<sup>88</sup> In operating theatres, EPR implementation was associated with significant increases in patient turnaround time of around 20%, which returned to baseline by 6 months.<sup>89</sup> Implementation of EPR should generally be expected to be associated with an initial decrease in efficiency during the first 6–12 months<sup>90</sup> and strategies should be developed to minimise this.<sup>91</sup>

Few studies report direct effects on patient outcome, most focusing on billing and efficiency, but in one intensive care unit (ICU) study, whilst there was no significant difference in length of stay or readmission rates, there was significant reduction in central-line infection and overall mortality rates.<sup>92</sup> Similarly, another ICU study reported significantly decreased overall mortality, due to reduced medication errors.<sup>93</sup>

EPR use is associated with improved documentation<sup>94</sup> with indirect benefits for medical staff; in one study, doctors were called to the treatment unit less since therapists had clearer understanding of treatment plans.<sup>95</sup> EPR use may also be associated with benefits to healthcare staff beyond the

institution, including improvement in the quality and speed of discharge summaries.<sup>96</sup>

Since EPRs are associated with improved billing accuracy, initial costs may be offset long term. In one study, costs were recaptured within 16 months, with ongoing annual savings and no adverse effect on efficiency.<sup>97</sup> In another, overall productivity increased by around 5% per year post-full EPR implementation<sup>98</sup>; whilst productivity may initially fall, billing income may increase due to improved coding.<sup>99</sup> Furthermore, cost-savings include reduced medication errors, improved implementation of clinical practice guidelines, enhanced infection prevention and cost-effective diagnostic testing<sup>100</sup>; order-set creation and care pathway redesign have significant benefits.<sup>101</sup> Such guideline integration may require calculated and complex variables, hence workflows may require modification to collect such data.<sup>102</sup> In one study, care pathway EPR integration was associated with reduced nosocomial infections.<sup>103</sup>

EPR use is associated with improved laboratory safety and patient identification, less labelling and requesting errors and shorter response times.<sup>104</sup> EPR-based handover between staff is associated with reduced clerical errors, greater satisfaction and improved efficiency, accuracy and safety; (around 400 work hours saved annually in one service).<sup>105</sup> There is an improved identification of significant prescribing errors, which improves patient safety,<sup>106</sup> and in an ITU study, the medication error rate significantly decreased post-implementation, including ordering, dispensing and administration.<sup>107</sup>

A well-documented benefit is improved population-based screening, due to the ability to identify patient cohorts, alert clinicians and suggest protocols. For example, improvement in performance of annual medical and multidisciplinary assessments<sup>108</sup> and data quality,<sup>109</sup> recording of pressure sores,<sup>110,111</sup> and proportion of patients receiving 'optimal care'.<sup>112,113</sup> EPR use is associated with significantly improved rates of appropriate antithrombotic therapy, blood pressure control, HbA1c testing and smoking cessation intervention,<sup>114</sup> whilst in patients with diabetes, EPR use results in significantly less emergency visits, overall doctor visits and hospitalisations.<sup>115</sup> Abdominal aortic aneurysm screening rates improved where EPR alerts are used with significantly reduction in unscreened patients from 50% to 20%.<sup>116</sup> However, despite improved screening, there is little evidence for improvements in rates of raised blood pressure or obesity.<sup>117</sup>

## DISCUSSION

Existing literature describes factors influencing implementation success, such as leadership and management, infrastructure and staff training, and focuses on workflows and usability. In general, EPR implementation leads to improvements in documentation, screening performance and prescribing, whereas the minimal data are available in areas such as patient outcome. The findings presented will be of value to organisations considering how best to implement EPR systems.

However, several caveats should be applied when interpreting literature in this area. First, organisations have different starting points, in terms of clinical activity, processes, culture, infrastructure and extent of digitisation, prior to EPR implementation, all of which significantly affect the method of implementation and likely success. Second, studies presented are predominantly performed in isolation, addressing one specific area without accounting for effects on the overall organisation, for example, service management; 24/7 IT support will be required which may not have been the case with paper-based systems, with associated resource implications. A consistent message from centres that have embarked upon comprehensive implementations is that an 'inch-deep mile-wide' approach is favourable since niche customisation slows, and adds significant cost and risk, with an optimisation phase once the system is in use.

The management of staff expectations is consistently recognised as important. Since an EPR programme represents major organisational investment and change, staff and executives may have unrealistic expectations that all organisational problems will be solved when, in reality, new issues may be created. For example, workflow evaluation for EPR provides data that may have been previously unavailable, producing a more transparent view regarding the state of clinical services and processes that were previously not appreciated. Apparently new 'problems' appear and areas of non-compliance become highlighted. Similarly, since EPR allows formal control of organisational policies, such as role-based access and permissions, there may be resistance to the 'system' rather than underlying policies. Process planning requires the evaluation of current processes, which may uncover suboptimal practices; attempts to engineer a 'perfect' EPR process into an underlying system that requires change should be avoided. The EPR go-live should be regarded as a starting point for system and workflow optimisation, which also required appropriate resources.

Staff training and engagement are consistently highlighted to influence implementation success. However, the practicalities of achieving an appropriate training plan across all staff groups remains complex. Requirements for training must balance the need for training *versus* maintaining the operational

performance, with associated cost. For example, staff may work shifts, including night work, and training must ensure that all such staff are skilled without reducing clinical care. Focusing training to support clinical roles is also beneficial, with clinical context-based peer-led teaching having anecdotal reports of value.

IT literacy of staff may vary greatly, with some having poor computer skills, particularly those who selectively choose roles such as night shifts. Others, such as administrative staff, may be highly familiar with existing 'bespoke' systems, and have developed numerous workarounds/shortcuts to perform tasks quickly. For such people, the move to 'user-friendly' EPR systems may reduce their efficiency. Furthermore, since such administrative/secretarial staff have impact on clinical activities, awareness of the needs of their needs should be regarded of equal importance to 'front-line' staff. Indeed, there are anecdotal cases of administrative staff complaints leading to clinicians refusing to use systems.

The literature appears to under-represent technical factors, such as data migration and conversion from existing systems. The extent and complexity of these tasks depend on the organisational starting point, but awareness of current data systems and how data will integrate to EPR are of major importance for usability. For example, migrated data may behave differently to 'native' EPR data, there may be subtle nuances in field mapping/data translation which can lead to operational and/or safety issues. Furthermore, this process results in the examination of data quality and previously unknown issues may become apparent.

In conclusion, although implementation of an EPR system represents a highly complex change programme impacting the entire organisation, utilising findings from previous experience and research can provide a basis for future evidence-based decisions. Many factors relating in particular to programme leadership, IT infrastructure, adequate real-world staff training and workflow optimisation are reported in relation to implementation success. Whilst EPR systems result in improved clinical documentation, medication prescribing and population screening, demonstration of positive effects on clinical patient outcomes requires further research in many areas.

## REFERENCES

1. Akenroye AT, Kumthekar AA, Alevizos MK, Mowrey WB, Broder A, Al-Azmi SF, *et al.* Perspectives on electronic medical record implementation after two years of use in primary health care practice. In: Henriksen K, Battles JB, Marks ES, Lewin DI (Eds.). *Studies in Health Technology and Informatics* 2015;19(4):1–6. PMID:26150121.
2. Black S. Problems at Addenbrooke's caused by failure to implement electronic patient record system effectively. *BMJ* 2015;351:h5721. Available from: <https://doi.org/10.1136/bmj.h5721>.
3. Friedman LN, Halpern NA and Fackler JC. Implementing an electronic medical record. *Critical Care Clinics* 2007;23(3):347–81. Available from: <https://doi.org/10.1016/j.ccc.2007.05.001>. PMID:17900476.
4. Noblin AM, Cortelyou-Ward K and Ton S. Electronic health record implementations: applying the principles of monitoring and controlling to achieve success. *Health Care Management* 2011;30(1):45–50. Available from: <https://doi.org/10.1097/HCM.0b013e3182078b4f>.
5. Slight SP, Quinn C, Avery AJ, Bates DW and Sheikh A. A qualitative study identifying the cost categories associated with electronic health record implementation in the UK. *Journal of the American Medical Informatics Association* 2014;21(e2):e226–31. Available from: <https://doi.org/10.1136/amiajnl-2013-002404>. PMID:24523391; PMCID:PMC4173176.
6. Joukes E, Cornet R, Abu-Hanna A, de Bruijne M and de Keizer N. End-user expectations during an electronic health record

- implementation: a case study in two academic hospitals. *Studies in Health Technology and Informatics* 2015;210:501–5. PMID:25991198.
7. Ratwani R, Fairbanks T, Savage E, Adams K, Wittie M, Boone E, *et al.* Mind the Gap. A systematic review to identify usability and safety challenges and practices during electronic health record implementation. *Applied Clinical Informatics* 2016;7(4):1069–87. Available from: <https://doi.org/10.4338/ACI-2016-06-R-0105>. PMID:27847961; PMCid:PMC5228144.
  8. Houser SH and Johnson LA. Perceptions regarding electronic health record implementation among health information management professionals in Alabama: a statewide survey and analysis. *Perspectives in Health Information Management* 2008;5:6. PMID:18504505; PMCid:PMC2394577.
  9. Bobadilla JL, Roe CS, Estes P, Lackey J and Steltenkamp CL. Leveraging electronic health record implementation to facilitate clinical and operational quality improvement in an ambulatory surgical clinic. *Journal of Ambulatory Care Management* 2017;40(1):9–16. Available from: <https://doi.org/10.1097/JAC.000000000000170>. PMID:27902548.
  10. Clarke A, Adamson J, Sheard L, Cairns P, Watt I and Wright J. Implementing electronic patient record systems (EPRs) into England's acute, mental health and community care trusts: a mixed methods study. *BMC Medical Informatics and Decision Making* 2015;15:85. Available from: <https://doi.org/10.1186/s12911-015-0204-0>. PMID:26466894; PMCid:PMC4607108.
  11. Chan KS, Kharrazi H, Parikh MA and Ford EW. Assessing electronic health record implementation challenges using item response theory. *American Journal of Managed Care* 2016;22(12):e409–15. PMID:27982669.
  12. McAlearney AS, Hefner JL, Sieck CJ and Huerta TR. The journey through grief: insights from a qualitative study of electronic health record implementation. *Health Services Research* 2015;50(2):462–88. Available from: <https://doi.org/10.1111/1475-6773.12227>. PMID:25219627; PMCid:PMC4369218.
  13. Bloomfield RAJ, Polo-Wood F, Mandel JC and Mandl KD. Opening the Duke electronic health record to apps: implementing SMART on FHIR. *International Journal of Medical Informatics* 2017;99:1–10. Available from: <https://doi.org/10.1016/j.ijmedinf.2016.12.005>. PMID:28118917.
  14. Friend TH, Jennings SJ and Levine WC. Communication patterns in the perioperative environment during epic electronic health record system implementation. *Journal of Medical Systems* 2017;41(2):22. Available from: <https://doi.org/10.1007/s10916-016-0674-3>. PMID:28000116.
  15. Retchin SM and Wenzel RP. Electronic medical record systems at academic health centers: advantages and implementation issues. *Academic Medicine* 1999;74(5):493–8. Available from: <https://doi.org/10.1097/00001888-199905000-00013>. PMID:10353279.
  16. McAlearney AS, Robbins J, Hirsch A, Jorina M and Harrop JP. Perceived efficiency impacts following electronic health record implementation: an exploratory study of an urban community health center network. *International Journal of Medical Informatics* 2010;79(12):807–16. Available from: <https://doi.org/10.1016/j.ijmedinf.2010.09.002>. PMID:20961803.
  17. Crosson JC, Stroebel C, Scott JG, Stello B and Crabtree BF. Implementing an electronic medical record in a family medicine practice: communication, decision making, and conflict. *The Annals of Family Medicine* 2005;3(4):307–11. Available from: <https://doi.org/10.1370/afm.326>. PMID:16046562; PMCid:PMC1466907.
  18. Cresswell K, Morrison Z, Crowe S, Robertson A and Sheikh A. Anything but engaged: user involvement in the context of a national electronic health record implementation. *Informatics in Primary Care* 2011;19(4):191–206. Available from: <https://doi.org/10.14236/jhi.v19i4.814>.
  19. Scott JT, Rundall TG, Vogt TM and Hsu J. Kaiser Permanente's experience of implementing an electronic medical record: a qualitative study. *BMJ* 2005;331(7528):1313–6. Available from: <https://doi.org/10.1136/bmj.38638.497477.68>. PMID:16269467; PMCid:PMC1298854.
  20. Samoutis G, Soteriades ES, Kounalakis DK, Zachariadou T, Philalithis A and Lionis C. Implementation of an electronic medical record system in previously computer-naïve primary care centres: a pilot study from Cyprus. *Informatics in Primary Care* 2007;15(4):207–16. PMID:18237477.
  21. Wibe T, Edwin E, Husby EH and Vedal T. Implementation of nursing care plan in the electronic patient record (EPR) findings and experiences. *Studies in Health Technology and Informatics* 2006;122:309–13. PMID:17102270.
  22. Terry AL, Brown JB, Bestard Denomme L, Thind A and Stewart M. Perspectives on electronic medical record implementation after two years of use in primary health care practice. *The Journal of the American Board of Family Medicine* 2012;25(4):522–7. Available from: <https://doi.org/10.3122/jabfm.2012.04.110089>. PMID:22773720.
  23. Mc Quaid L, Breen P, Grimson J, Normand C, Dunne M, Delanty N, *et al.* Socio-technical considerations in epilepsy electronic patient record implementation. *International Journal of Medical Informatics* 2010;79(5):349–60. Available from: <https://doi.org/10.1016/j.ijmedinf.2010.01.013>. PMID:20181511.
  24. McAlearney AS, Sieck C, Hefner J, Robbins J and Huerta TR. Facilitating ambulatory electronic health record system implementation: evidence from a qualitative study. *BioMed Research International* 2013;2013:629574. Available from: <https://doi.org/10.1155/2013/629574>. PMID:24228257; PMCid:PMC3817798.
  25. Jensen RE, Chan KS, Weiner JP, Fowles JB and Neale SM. Implementing electronic health record-based quality measures for developmental screening. *Pediatrics* 2009;124(4):e648–54. Available from: <https://doi.org/10.1542/peds.2008-3091>. PMID:19786425.
  26. McAlearney AS, Hefner JL, Sieck C, Rizer M and Huerta TR. Fundamental issues in implementing an ambulatory care electronic health record. *The Journal of the American Board of Family Medicine* 2015;28(1):55–64. Available from: <https://doi.org/10.3122/jabfm.2015.01.140078>. PMID:25567823.
  27. Harle CA, Listhaus A, Covarrubias CM, Schmidt SO, Mackey S, Carek PJ, *et al.* Overcoming barriers to implementing patient-reported outcomes in an electronic health record: a case report. *Journal of the American Medical Informatics Association* 2016;23(1):74–9. Available from: <https://doi.org/10.1093/jamia/ocv085>. PMID:26159464; PMCid:PMC5009936.
  28. Scantlebury A, Sheard L, Watt I, Cairns P, Wright J and Adamson J. Exploring the implementation of an electronic record into a maternity unit: a qualitative study using Normalisation Process

- Theory. *BMC Medical Informatics and Decision Making* 2017;17(1):4. Available from: <https://doi.org/10.1186/s12911-016-0406-0>. PMID:28061781; PMCID:PMC5219748.
29. Souther E. Implementation of the electronic medical record: the team approach. *Computers in Nursing* 2001;19(2):47–55. PMID:11280148.
  30. Fletcher GS and Payne TH. Selection and implementation of an electronic health record. *PM&R* 2017;9(5S):S4–12. Available from: <https://doi.org/10.1016/j.pmrj.2017.02.007>. PMID:28527502.
  31. Yoon-Flannery K, Zandieh SO, Kuperman GJ, Langsam DJ, Hyman D and Kaushal R. A qualitative analysis of an electronic health record (EHR) implementation in an academic ambulatory setting. *Journal of Innovation in Health Informatics* 2008;16(4):277–84. Available from: <https://doi.org/10.14236/jhi.v16i4.703>.
  32. Collinworth AW, Masica AL, Priest EL, Berryman CD, Kouznetsova M, Glorioso O, et al. Modifying the electronic health record to facilitate the implementation and evaluation of a bundled care program for intensive care unit delirium. *EGEMS* 2014;2(1):1121. Available from: <https://doi.org/10.13063/2327-9214.1121>.
  33. Ghazisaeidi M, Ahmadi M, Sadoughi F and Safdari R. An assessment of readiness for pre-implementation of electronic health record in Iran: a practical approach to implementation in general and teaching hospitals. *Acta Medica Iranica* 2014;52(7):532–44. PMID:25135263.
  34. Cucciniello M, Lapsley I, Nasi G and Pagliari C. Understanding key factors affecting electronic medical record implementation: a sociotechnical approach. *BMC Health Services Research* 2015;15:268. Available from: <https://doi.org/10.1186/s12913-015-0928-7>. PMID:26184405; PMCID:PMC4504039.
  35. Gross AH, Leib RK, Tonachel A, Tonachel R, Bowers DM, Burnard RA, et al. Teamwork and electronic health record implementation: a case study of preserving effective communication and mutual trust in a changing environment. *Journal of Oncology Practice* 2016;12(11):1075–83. Available from: <https://doi.org/10.1200/JOP.2016.013649>. PMID:27601513.
  36. Fullerton C, Aponte P, Hopkins R, Bragg D and Ballard DJ. Lessons learned from pilot site implementation of an ambulatory electronic health record. *Baylor University Medical Center Proceedings* 2006;19(4):303–10. Available from: <https://doi.org/10.1080/08998280.2006.11928188>. PMID:17106488; PMCID:PMC1618740.
  37. Corrao NJ, Robinson AG, Swiernik MA and Naeim A. Importance of testing for usability when selecting and implementing an electronic health or medical record system. *Journal of Oncology Practice* 2010;6(3):120–4. Available from: <https://doi.org/10.1200/JOP.200017>. PMID:20808553; PMCID:PMC2868635.
  38. Badger SL, Bosch RG and Toteja P. Rapid implementation of an electronic health record in an academic setting. *Journal of Healthcare Information Management* 2005;19(2):34–40. PMID:15869211.
  39. Laramee AS, Bosek M, Kasprisin CA and Powers-Phaneuf T. Learning from within to ensure a successful implementation of an electronic health record. *Computers, Informatics, Nursing* 2011;29(8):468–9. Available from: <https://doi.org/10.1097/NCN.0b013e3181fc3fc7>. PMID:21076282.
  40. Scott K and Van Norman J. Managing the complexity of a systemwide electronic medical record design and implementation: lessons for nurse leaders. *Nursing Administration Quarterly* 2009;33(2):109–15. Available from: <https://doi.org/10.1097/NAQ.0b013e3181a10c64>. PMID:19305307.
  41. Zeng X. The impacts of electronic health record implementation on the health care workforce. *North Carolina Medical Journal* 2016;77(2):112–4. Available from: <https://doi.org/10.18043/ncm.77.2.112>.
  42. Lee T-T and Chang C-P. Nurses' experiences of an initial and re-implemented electronic health record use. *Studies in Health Technology and Informatics* 2016;225:802–3. PMID:27332349.
  43. McAlearney AS, Song PH, Robbins J, Hirsch A, Jorina M, Kowalczyk N, et al. Moving from good to great in ambulatory electronic health record implementation. *Journal for Healthcare Quality* 2010;32(5):41–50. Available from: <https://doi.org/10.1111/j.1945-1474.2010.00107.x>. PMID:20854358.
  44. Craven CK, Sievert MC, Hicks LL, Alexander GL, Hearne LB and Holmes JH. Experts speak: advice from key informants to small, rural hospitals on implementing the electronic health record system. *Studies in Health Technology and Informatics* 2013;192:608–12. PMID:23920628.
  45. Bach DS, Risko KR, Zaran FK, Farber MS and Polk GJ. A pharmacy blueprint for electronic medical record implementation success. *Hospital Pharmacy* 2015;50(6):484–95. Available from: <https://doi.org/10.1310/hpj5006-484>. PMID:26405340; PMCID:PMC4568109.
  46. Meeks DW, Takian A, Sittig DF, Singh H and Barber N. Exploring the sociotechnical intersection of patient safety and electronic health record implementation. *Journal of the American Medical Informatics Association* 2014;21(e1):e28–34. Available from: <https://doi.org/10.1136/amiajnl-2013-001762>. PMID:24052536; PMCID:PMC3957388.
  47. McAlearney AS, Hefner JL, Sieck C, Rizer M and Huerta TR. Evidence-based management of ambulatory electronic health record system implementation: an assessment of conceptual support and qualitative evidence. *International Journal of Medical Informatics* 2014;83(7):484–94. Available from: <https://doi.org/10.1016/j.ijmedinf.2014.04.002>. PMID:24862893.
  48. Rizer MK, Kaufman B, Sieck CJ, Hefner JL and McAlearney AS. Top 10 lessons learned from electronic medical record implementation in a large academic medical center. *Perspectives in Health Information Management* 2015;12:1g. PMID:26396558; PMCID:PMC4558484.
  49. Mikulich VJ, Liu YC, Steinfeldt J and Schriger DL. Implementation of clinical guidelines through an electronic medical record: physician usage, satisfaction and assessment. *International Journal of Medical Informatics* 2001;63(3):169–78. Available from: [https://doi.org/10.1016/S1386-5056\(01\)00177-0](https://doi.org/10.1016/S1386-5056(01)00177-0).
  50. Jones MR. Computers can land people on Mars, why can't they get them to work in a hospital? Implementation of an Electronic Patient Record System in a UK Hospital. *Methods of Information in Medicine* 2003;42(4):410–5. Available from: <https://doi.org/10.1055/s-0038-1634238>. PMID:14534642.
  51. Hier DB, Rothschild A, LeMaistre A and Keeler J. Differing faculty and housestaff acceptance of an electronic health record

- one year after implementation. *Studies in Health Technology and Informatics* 2004;107(Pt 2):1300–3. PMID:15361024.
52. Doyle RJ, Wang N, Anthony D, Borkan J, Shield RR and Goldman RE. Computers in the examination room and the electronic health record: physicians' perceived impact on clinical encounters before and after full installation and implementation. *Family Practice* 2012;29(5):601–8. Available from: <https://doi.org/10.1093/fampra/cms015>. PMID:22379185.
  53. Brotzman GL, Guse CE, Fay DL, Schellhase KG and Marbella AM. Implementing an electronic medical record at a residency site: physicians' perceived effects on quality of care, documentation, and productivity. *WJM* 2009;108(2):99–103. PMID:19437936.
  54. Spencer DC, Choi D, English C and Girard D. The effects of electronic health record implementation on medical student educators. *Teaching and Learning in Medicine* 2012;24(2):106–10. Available from: <https://doi.org/10.1080/10401334.2012.664513>. PMID:22490089.
  55. Chisolm DJ, Purnell TS, Cohen DM and McAlearney AS. Clinician perceptions of an electronic medical record during the first year of implementation in emergency services. *Pediatric Emergency Care* 2010;26(2):107–10. Available from: <https://doi.org/10.1097/PEC.0b013e3181ce2f99>. PMID:20093997; PMCID:PMC2946791.
  56. Fleurant M, Kell R, Jenter C, Volk LA, Zhang F, Bates DW, et al. Factors associated with difficult electronic health record implementation in office practice. *Journal of the American Medical Informatics Association* 2012;19(4):541–4. Available from: <https://doi.org/10.1136/amiainl-2011-000689>. PMID:22249965; PMCID:PMC3384124.
  57. Takian A, Sheikh A and Barber N. We are bitter, but we are better off: case study of the implementation of an electronic health record system into a mental health hospital in England. *BMC Health Services Research* 2012;12:484. Available from: <https://doi.org/10.1186/1472-6963-12-484>. PMID:23272770; PMCID:PMC3545968.
  58. Nour El Din MM. Physicians' use of and attitudes toward electronic medical record system implemented at a teaching hospital in Saudi Arabia. *The Journal of the Egyptian Public Health Association* 2007;82(5–6):347–64. PMID:18706293.
  59. Shield RR, Goldman RE, Anthony DA, Wang N, Doyle RJ and Borkan J. Gradual electronic health record implementation: new insights on physician and patient adaptation. *The Annals of Family Medicine* 2010;8(4):316–26. Available from: <https://doi.org/10.1370/afm.1136>. PMID:20644186; PMCID:PMC2906526.
  60. Ehrlich JR, Michelotti M, Blachley TS, Zheng K, Couper MP, Greenberg GM, et al. A two-year longitudinal assessment of ophthalmologists' perceptions after implementing an electronic health record system. *Applied Clinical Informatics* 2016;7(4):930–45. Available from: <https://doi.org/10.4338/ACI-2016-05-RA-0075>. PMID:27730248; PMCID:PMC5228135.
  61. Wylie MC, Baier RR and Gardner RL. Perceptions of electronic health record implementation: a statewide survey of physicians in Rhode Island. *The American Journal of Medicine* 2014;127(10):1010.e21–7. Available from: <https://doi.org/10.1016/j.amjmed.2014.06.011>. PMID:24945882.
  62. Crowson MG, Vail C and Eapen RJ. Influence of electronic medical record implementation on provider retirement at a major academic medical centre. *Journal of Evaluation in Clinical Practice* 2016;22(2):222–6. Available from: <https://doi.org/10.1111/jep.12458>. PMID:26395432.
  63. Claret P-G, Sebbanne M, Bobbia X, Bonnet J-M, Pommet S, Jebali C, et al. First medical contact and physicians' opinion after the implementation of an electronic record system. *The American Journal of Emergency Medicine* 2012;30(7):1235–40. Available from: <https://doi.org/10.1016/j.ajem.2011.06.014>. PMID:22030205.
  64. Sicotte C, Clavel S and Fortin MA. A cancer care electronic medical record highly integrated into clinicians' workflow: users' attitudes pre-post implementation. *European Journal of Cancer Care* 2016;26(6):e12548.
  65. Moreland PJ, Gallagher S, Bena JF, Morrison S and Albert NM. Nursing satisfaction with implementation of electronic medication administration record. *Computers, Informatics, Nursing* 2012;30(2):97–103. Available from: <https://doi.org/10.1097/NCN.0b013e318224b54e>. PMID:21993338.
  66. Tubaishat A. Evaluation of electronic health record implementation in hospitals. *Computers, Informatics, Nursing* 2017;35(7):364–72. Available from: <https://doi.org/10.1097/CIN.0000000000000328>.
  67. Laramee AS, Bosek M, Shaner-McRae H and Powers-Phaneuf T. A comparison of nurse attitudes before implementation and 6 and 18 months after implementation of an electronic health record. *Computers, Informatics, Nursing* 2012;30(10):521–30. Available from: <https://doi.org/10.1097/NXN.0b013e3182573b04>.
  68. Taylor SP, Ledford R, Palmer V and Abel E. We need to talk: an observational study of the impact of electronic medical record implementation on hospital communication. *BMJ Quality & Safety* 2014;23(7):584–8. Available from: <https://doi.org/10.1136/bmjqs-2013-002436>. PMID:24505111.
  69. Irizarry T and Barton AJ. A sociotechnical approach to successful electronic health record implementation: five best practices for clinical nurse specialists. *Clinical Nurse Specialist* 2013;27(6):283–5. Available from: <https://doi.org/10.1097/NUR.0b013e3182a872e3>. PMID:24107749.
  70. Nagy VT and Kanter MH. Implementing the electronic medical record in the exam room: the effect on physician-patient communication and patient satisfaction. *The Permanente Journal* 2007;11(2):21–4. Available from: <https://doi.org/10.7812/TPP/06-118>. PMID:21461089; PMCID:PMC3057731.
  71. Al-Azmi SF, Mohammed AM and Hanafi MI. Patients' satisfaction with primary health care in Kuwait after electronic medical record implementation. *The Journal of the Egyptian Public Health Association* 2006;81(5–6):277–300. PMID:18706302.
  72. Schnipper JL, Gandhi TK, Wald JS, Grant RW, Poon EG, Volk LA, et al. Design and implementation of a web-based patient portal linked to an electronic health record designed to improve medication safety: the Patient Gateway medications module. *Journal of Innovation in Health Informatics* 2008;16(2):147–55. Available from: <https://doi.org/10.14236/jhi.v16i2.686>.
  73. Ose D, Kunz A, Pohlmann S, Hofmann H, Qreini M, Krisam J, et al. A personal electronic health record: study protocol of a feasibility study on implementation in a real-world health care setting. *JMIR Research Protocols* 2017;6(3):e33. Available

- from: <https://doi.org/10.2196/resprot.6314>. PMID:28254735; PMCID:PMC5355628.
74. Kirkpatrick JP, Light KL, Walker RM, Georgas DL, Antoine PA, Clough RW, *et al.* Implementing and integrating a clinically driven electronic medical record for radiation oncology in a large medical enterprise. *Frontiers in Oncology* 2013;3:69. Available from: <https://doi.org/10.3389/fonc.2013.00069>. PMID:23616946; PMCID:PMC3629369.
  75. Keshavjee K, Troyan S, Holbrook AM and VanderMolen D. Measuring the success of electronic medical record implementation using electronic and survey data. *Proceedings AMIA Symposium*, 2001, pp. 309–13. PMID:11825201; PMCID:PMC2243411.
  76. Wormer BA, Colavita PD, Yokeley WT, Bradley JF 3rd, Williams KB, Walters AL, *et al.* Impact of implementing an electronic health record on surgical resident work flow, duty hours, and operative experience. *American Surgeon* 2015;81(2):172–7. PMID:25642880.
  77. Yadav S, Kazanji N, K C N, Paudel S, Falatko J, Shoichet S, *et al.* Comparison of accuracy of physical examination findings in initial progress notes between paper charts and a newly implemented electronic health record. *Journal of the American Medical Informatics Association* 2017;24(1):140–4. Available from: <https://doi.org/10.1093/jamia/ocw067>. PMID:27357831.
  78. Pizziferri L, Kittler AF, Volk LA, Honour MM, Gupta S, Wang S, *et al.* Primary care physician time utilization before and after implementation of an electronic health record: a time-motion study. *Journal of Biomedical Informatics* 2005;38(3):176–88. Available from: <https://doi.org/10.1016/j.jbi.2004.11.009>. PMID:15896691.
  79. Verwey R, Claassen RAB, Rutgers MJ and de Witte LP. The implementation of an electronic nursing record in a general hospital in the Netherlands: lessons to learn. *Studies in Health Technology and Informatics* 2008;141:130–8. PMID:18953133.
  80. Chiang MF, Read-Brown S, Tu DC, Choi D, Sanders DS, Hwang TS, *et al.* Evaluation of electronic health record implementation in ophthalmology at an academic medical center (an American Ophthalmological Society thesis). *Transactions of the American Ophthalmological Society* 2013;111:70–92.
  81. Spellman Kennebeck S, Timm N, Farrell MK and Spooner SA. Impact of electronic health record implementation on patient flow metrics in a pediatric emergency department. *Journal of the American Medical Informatics Association* 2012;19(3):443–7. Available from: <https://doi.org/10.1136/amiajn-2011-000462>. PMID:22052897; PMCID:PMC3341791.
  82. Ward MJ, Froehle CM, Hart KW, Collins SP and Lindsell CJ. Transient and sustained changes in operational performance, patient evaluation, and medication administration during electronic health record implementation in the emergency department. *Annals of Emergency Medicine* 2014;63(3):320–8. Available from: <https://doi.org/10.1016/j.annemergmed.2013.08.019>. PMID:24041783; PMCID:PMC3961764.
  83. Ward MJ, Landman AB, Case K, Berthelot J, Pilgrim RL and Pines JM. The effect of electronic health record implementation on community emergency department operational measures of performance. *Annals of Emergency Medicine* 2014;63(6):723–30. Available from: <https://doi.org/10.1016/j.annemergmed.2013.12.019>. PMID:24412667; PMCID:PMC4059411.
  84. Reddy KG and Yu JC. The impact of electronic medical record implementation on the outpatient volumes of a midsize academic center. *Annals of Plastic Surgery* 2014;73(3):330–2. Available from: <https://doi.org/10.1097/SAP.0000000000000314>. PMID:25046676.
  85. Patterson ME, Marken P, Zhong Y, Simon SD and Ketcherside W. Comprehensive electronic medical record implementation levels not associated with 30-day all-cause readmissions within Medicare beneficiaries with heart failure. *Applied Clinical Informatics* 2014;5(3):670–84. Available from: <https://doi.org/10.4338/ACI-2014-01-RA-0008>. PMID:25298808; PMCID:PMC4187085.
  86. Rupp KJ, Ham NJ, Blankenship DE, Payton ME and Murray KA. Pre and post hoc analysis of electronic health record implementation on emergency department metrics. *Baylor University Medical Center Proceedings* 2017;30(2):147–50. Available from: <https://doi.org/10.1080/08998280.2017.11929563>. PMID:28405062; PMCID:PMC5349808.
  87. Singh RP, Bedi R, Li A, Kulkarni S, Rodstrom T, Altus G, *et al.* The practice impact of electronic health record system implementation within a large multispecialty ophthalmic practice. *JAMA Ophthalmology* 2015;133(6):668–74. Available from: <https://doi.org/10.1001/jamaophthalmol.2015.0457>. PMID:25880083.
  88. Haidar YM, Moshtaghi O, Mahboubi H, Ghavami Y, Ziai K, Hojjat H, *et al.* Association between electronic medical record implementation and otolaryngologist productivity in the ambulatory setting. *JAMA Otolaryngology Head & Neck Surgery* 2017;143(1):20–4. Available from: <https://doi.org/10.1001/jamaoto.2016.2528>. PMID:27583577.
  89. McDowell J, Wu A, Ehrenfeld JM and Urman RD. Effect of the implementation of a new electronic health record system on surgical case turnover time. *Journal of Medical Systems* 2017;41(3):42. Available from: <https://doi.org/10.1007/s10916-017-0690-y>. PMID:28130725.
  90. Risko N, Anderson D, Golden B, Wasil E, Barrueto F, Pimentel L, *et al.* The impact of electronic health record implementation on emergency physician efficiency and patient throughput. *Healthcare* 2014;2(3):201–4. Available from: <https://doi.org/10.1016/j.hjdsi.2014.06.003>. PMID:26250507.
  91. Thirukumaran CP, Dolan JG, Reagan Webster P, Panzer RJ and Friedman B. The impact of electronic health record implementation and use on performance of the surgical care improvement project measures. *Health Services Research* 2015;50(1):273–89. Available from: <https://doi.org/10.1111/1475-6773.12191>. PMID:24965357; PMCID:PMC4319882.
  92. Flatow VH, Ibragimova N, Divino CM, Eshak DSA, Twohig BC, Bassily-Marcus AM, *et al.* Quality outcomes in the surgical intensive care unit after electronic health record implementation. *Applied Clinical Informatics* 2015;6(4):611–8. Available from: <https://doi.org/10.4338/ACI-2015-04-RA-0044>. PMID:26767058; PMCID:PMC4704031.
  93. Han JE, Rabinovich M, Abraham P, Satyanarayana P, Liao TV, Udoji TN, *et al.* Effect of electronic health record implementation in critical care on survival and medication errors. *The American Journal of the Medical Sciences* 2016;351(6):576–81. Available from: <https://doi.org/10.1016/j.amjms.2016.01.026>. PMID:27238919.

94. Rosenbloom ST, Qi X, Riddle WR, Russell WE, DonLevy SC, Giuse D, *et al.* Implementing pediatric growth charts into an electronic health record system. *Journal of the American Medical Informatics Association* 2006;13(3):302–8. Available from: <https://doi.org/10.1197/jamia.M1944>. PMID:16501182; PMCID:PMC1513651.
95. Albuquerque KV, Miller AA and Roeske JC. Implementation of electronic checklists in an oncology medical record: initial clinical experience. *Journal of Oncology Practice* 2011;7(4):222–6. Available from: <https://doi.org/10.1200/JOP.2011.000237>. PMID:22043184; PMCID:PMC3140442.
96. Dean SM, Gilmore-Bykovskiy A, Buchanan J, Ehlenfeldt B and Kind AJH. Design and hospitalwide implementation of a standardized discharge summary in an electronic health record. *The Joint Commission Journal on Quality and Patient Safety* 2016;42(12):555–AP11. Available from: [https://doi.org/10.1016/S1553-7250\(16\)30107-6](https://doi.org/10.1016/S1553-7250(16)30107-6).
97. Grieger DL, Cohen SH and Krusch DA. A pilot study to document the return on investment for implementing an ambulatory electronic health record at an academic medical center. *Journal of the American College of Surgeons* 2007;205(1):89–96. Available from: <https://doi.org/10.1016/j.jamcollsurg.2007.02.074>. PMID:17617337.
98. Evans DC, Nichol WP and Perlin JB. Effect of the implementation of an enterprise-wide electronic health record on productivity in the Veterans Health Administration. *Health Economics, Policy and Law* 2006;1(Pt 2):163–9. Available from: <https://doi.org/10.1017/S1744133105001210>. PMID:18634688.
99. Howley MJ, Chou EY, Hansen N and Dalrymple PW. The long-term financial impact of electronic health record implementation. *Journal of the American Medical Informatics Association* 2015;22(2):443–52. Available from: <https://doi.org/10.1136/amiajnl-2014-002686>. PMID:25164255.
100. Riahi S, Fischler I, Stuckey MI, Klassen PE and Chen J. The value of electronic medical record implementation in mental health care: a case study. *JMIR Medical informatics* 2017;5(1):e1. Available from: <https://doi.org/10.2196/medinform.6512>. PMID:28057607; PMCID:PMC5247622.
101. Hulse NC, Lee J and Borgeson T. Visualization of order set creation and usage patterns in early implementation phases of an electronic health record. *AMIA: Annu Symposium Proceedings & AMIA Symposium* 2016;2016:657–66.
102. Sonnenberg FA, Hagerty CG, Acharya J, Pickens DS and Kulikowski CA. Vocabulary requirements for implementing clinical guidelines in an electronic medical record: a case study. *AMIA: Annu Symposium Proceedings & AMIA Symposium* 2005;709–13.
103. Cook PP, Rizzo S, Gooch M, Jordan M, Fang X and Hudson S. Sustained reduction in antimicrobial use and decrease in methicillin-resistant *Staphylococcus aureus* and *Clostridium difficile* infections following implementation of an electronic medical record at a tertiary-care teaching hospital. *Journal of Antimicrobial Chemotherapy* 2011;66(1):205–9. Available from: <https://doi.org/10.1093/jac/dkq404>. PMID:21059617.
104. Gascon F, Herrera I, Vazquez C, Jimenez P, Jimenez J, Real C, *et al.* Electronic health record: design and implementation of a lab test request module. *International Journal of Medical Informatics* 2013;82(6):514–21. Available from: <https://doi.org/10.1016/j.ijmedinf.2013.03.006>. PMID:23602410.
105. Raval MV, Rust L, Thakkar RK, Kurtovic KJ, Nwomeh BC, Besner GE, *et al.* Development and implementation of an electronic health record generated surgical handoff and rounding tool. *Journal of Medical Systems* 2015;39(2):8. Available from: <https://doi.org/10.1007/s10916-015-0202-x>. PMID:25631842.
106. Finn A, Bondarenka C, Edwards K, Hartwell R, Letton C and Perez A. Evaluation of electronic health record implementation on pharmacist interventions related to oral chemotherapy management. *Journal of Oncology Pharmacy Practice* 2016;23(8):563–74. PMID:27573921.
107. Carayon P, Wetterneck TB, Cartmill R, Blosky MA, Brown R, Hoonakker P, *et al.* Medication safety in two intensive care units of a community teaching hospital after electronic health record implementation: sociotechnical and human factors engineering considerations. *Journal of Patient Safety* 2017. doi: 10.1097/PTS.0000000000000358. [Epub ahead of print]. PMID: 28248749. Available from: <https://doi.org/10.1097/PTS.0000000000000358>. PMID:28248749.
108. Kritz S, Brown LSJ, Chu M, John-Hull C, Madray C, Zavala R, *et al.* Electronic medical record system at an opioid agonist treatment programme: study design, pre-implementation results and post-implementation trends. *Journal of Evaluation in Clinical Practice* 2012;18(4):739–45. Available from: <https://doi.org/10.1111/j.1365-2753.2011.01664.x>. PMID:21414112; PMCID:PMC3539283.
109. Harshberger CA, Harper AJ, Carro GW, Spath WE, Hui WC, Lawton JM, *et al.* Outcomes of computerized physician order entry in an electronic health record after implementation in an outpatient oncology setting. *Journal of Oncology Practice* 2011;7(4):233–7. Available from: <https://doi.org/10.1200/JOP.2011.000261>. PMID:22043187; PMCID:PMC3140445.
110. Gunningberg L, Dahm MF and Ehrenberg A. Accuracy in the recording of pressure ulcers and prevention after implementing an electronic health record in hospital care. *Quality and Safety in Health Care* 2008;17(4):281–5. Available from: <https://doi.org/10.1136/qshc.2007.023341>. PMID:18678726.
111. Gunningberg L, Fogelberg-Dahm M and Ehrenberg A. Improved quality and comprehensiveness in nursing documentation of pressure ulcers after implementing an electronic health record in hospital care. *Journal of Clinical Nursing* 2009;18(11):1557–64. Available from: <https://doi.org/10.1111/j.1365-2702.2008.02647.x>. PMID:19220607.
112. Herrin J, da Graca B, Nicewander D, Fullerton C, Aponte P, Stanek G, *et al.* The effectiveness of implementing an electronic health record on diabetes care and outcomes. *Health Services Research* 2012;47(4):1522–40. Available from: <https://doi.org/10.1111/j.1475-6773.2011.01370.x>. PMID:22250953; PMCID:PMC3401397.
113. McGuire MJ, Noronha G, Samal L, Yeh H-C, Crocetti S and Kravet S. Patient safety perceptions of primary care providers after implementation of an electronic medical record system. *Journal of General Internal Medicine* 2013;28(2):184–92. Available from: <https://doi.org/10.1007/s11606-012-2153-y>. PMID:22887020; PMCID:PMC3614133.

114. Wang JJ, Sebek KM, McCullough CM, Amirfar SJ, Parsons AS, Singer J, *et al.* Sustained improvement in clinical preventive service delivery among independent primary care practices after implementing electronic health record systems. *Preventing Chronic Disease* 2013;10:E130. PMID:23906330; PMCID:PMC3733479.
115. Reed M, Huang J, Brand R, Graetz I, Neugebauer R, Fireman B, *et al.* Implementation of an outpatient electronic health record and emergency department visits, hospitalizations, and office visits among patients with diabetes. *JAMA* 2013;310(10):1060–5. Available from: <https://doi.org/10.1001/jama.2013.276733>. PMID:24026601; PMCID:PMC4503235.
116. Hye RJ, Smith AE, Wong GH, Vansomphone SS, Scott RD and Kanter MH. Leveraging the electronic medical record to implement an abdominal aortic aneurysm screening program. *Journal of Vascular Surgery* 2014;59(6):1535–42. Available from: <https://doi.org/10.1016/j.jvs.2013.12.016>. PMID:24507825.
117. Akenroye AT, Kumthekar AA, Alevizos MK, Mowrey WB and Broder A. Implementing an electronic medical record-based reminder for cardiovascular risk screening in rheumatoid arthritis. *Arthritis Care & Research* 2017;69(5):625–32. Available from: <https://doi.org/10.1002/acr.22966>. PMID:27390217.