Impact of Electronic Health Record on Chronic Disease Management

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***Abstract*—** The aim of this study is to review published articles to assess the impact of EHR on chronic disease management.Thirteen full articles published from year 2003 to 2009 in the *Medline* and *Pubmed* database were retrieved for further review. Three articles met our criteria and were selected as the final set of study. Of the three studied articles, one study agreed that EHR improved chronic disease management; another concluded that it partially improved, and the other argued that it failed to achieve desirable levels of care improvement. Study result shows that EHR has 33.5% likelihood positive impact on chronic disease management.

***Keywords*—** Chronic disease, EHR, AHP, Evaluation

1. INTRODUCTION

A Chronic disease is an illness lasting a long time. By definition of the U.S. Center for Health Statistics, a chronic disease is a disease lasting 3 months or more. Managing chronic disease is now a large and growing problem for health care system in many developed countries in the world [1-4]. A recent study, supported by Danish pharmaceutical company Novo Nordisk A/S, estimated that diabetes could cost U.S. well over $218 billion. Nearly all healthcare stakeholders recognize that introducing Health Information Technology (HIT) to chronic disease management will cut soaring costs, and improve care quality [5, 6]. Electronic Health Record (EHR) is a HIT that allows health record of an individual is accessible online from many separate, interoperable automated systems within an electronic network. It is believed essential in improving chronic disease management [7-9].

As with any other health care innovation, EHRs should be rigorously evaluated before widespread dissemination into clinical practice. However, few researches have systematically studied the impact of EHR on chronic disease management, i.e., Does EHR impact on chronic disease management? This research attempts to provide a cumulative summary to answer the following two questions: (1) Does EHR improve chronic disease care management including patient outcome and cost saving? and (2) Which EHR and study level factors are associated with effective EHRs?

2. STUDY METHOD

2.1. Data Selection

We defined an Electronic Health Record (EHR) as "*a shared record of an individual's past and present health status, care received, and plan of care, delivered through secure electronic systems that combine this information with decision support and workflow tools tailored to the context of care delivery.*" Its scope covers Electronic Medical Record (EMR) and Electronic Patient Record (EPR) [10]. In this research, we used EHR as an alternative term for EMR and EPR. We also defined the chronic disease as "*a disease that is long-lasting or recurrent.*" Therefore, diabetes mellitus, chronic renal disease, and cardiovascular diseases (e.g. heart failure, ischemic cardiopathy, cerebrovascular disease) are all chronic diseases. Based on these definitions, we use "electronic health record", "EHR", "chronic diseases", "chronic illness", "chronic", "diabetes", "renal disease", "cardiovascular diseases" and their AND/OR combinations as key words, text words, phrases to search literatures published from year 2003 to 2008 in the *Medline* and *Pubmed* database. Thirteen full articles were retrieved for further review. Next, we used *quantitative research*, *journal impact factor*, and *article published year* as inclusion criteria, and *review paper*, *qualitative research*, *proceedings paper*, and r*epeated author* as exclusion criteria to select three articles as the final set of study. The three articles [5, 6, 11] described EHR, EMR and EPR impact on chronic disease management.

2.2. Analysis Method

Many previous researches used predefined quality analysis (QA) criteria and measurement tools (e.g. scale, index, checklist, guidance documents, etc.) to systematically evaluate the quality of systems or articles [12-15]. When scale measurement was used, the weight for each criterion was usually assigned equal value [16-18]. However, this equal value assumption is not realistic because different criterion should have different weight according to the evaluation goal. For example, the "method design" criterion should have higher weight than that of "presentation of article" criterion for evaluating *system impact* articles. With this in mind, this study attempts to apply Analytic Hierarchy Process (AHP) to determine the weights of criteria, and then use the weighted criteria to evaluate the selected articles. AHP is a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions [19].

First, based on IMIA [20], Garg et al. [18], and Francis Lou [21] evaluation schemes, we determine two main criteria: *significance* and *quality of scientific content* for the analysis (see Table 1). The *significance* includes four sub-criteria (A-1~4), and the *quality of scientific content* includes seven sub-criteria (B1~B7). Each sub-criterion also includes several sub-sub-criteria respectively. Next, we used Analytic Hierarchy Process to determine the weight for each criterion. The criteria were pairwise compared as to how important they are to the reviewers, with respect to the research goal. In this study, we consider A-1~4, B4-1~6, and B7-1~2 are useful criteria for the evaluation. Other criteria in Table 1 are not considered because they only contribute to the presentation quality of an article (e.g. B5). The AHP hierarchy for the criterion weight decision was constructed as in Figure 1. Once the hierarchy has been established, we used AHP to establish *priorities* for all its nodes (criteria).

The criterion weight vector is defined as follows:

$$\overline{W} = (w_1, w_2, \cdots, w_n)^t \quad (1)$$

The criterion pairwise comparison matrix is defined as equation (2)

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \dots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \quad (2)$$

Where $a_{ij} = w_i / w_j$, w_i, w_j is the weight of criterion i and j respectively, $a_{ij} = 1/a_{ji}$, and $a_{ij} = a_{ik} / a_{jk}$.

Then, we multiply (2) by (1) to obtain equation (3).

$$A\overline{W} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \dots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (3)$$

Equation (3) can also be re-expressed as follows:

$$(A - \lambda_{\max} I)\overline{W} = 0 \quad (4)$$

where $\lambda_{\max}$ is the maximum *Eigen value*.

When we solve equation (4) to obtain the maximum *Eigen vector* we also have the criterion weight vector (the criterion weight vector is equal to the maximum *Eigen vector*).

According to the above description, we firstly established judgment table for criteria. Following, we compared the criteria one by one to establish the corresponding *pairwise comparison matrix*. The final judgment table and corresponding pairwise comparison matrix for criterion A and B were shown in Figure 2, for criterion A1~4 were shown in Figure 3, for criterion B4 and B7 were shown in Figure 4, for criterion B4-1~6 were shown in Figure 5, and for criterion B7-1 and B7-2 were shown in Figure 6. Using these five matrixes and equation (4), and applying an AHP tool (http://www.cci-icc.gc.ca/tools/ ahp/index_ e.asp) we obtained every criterion's local weight as shown in Table 1 (also shown in Figure 1).

3. RESULT

3.1. Evaluation Scoring

We carefully reviewed three articles in the final set of study. Then, we applied the criteria listed in Table 1 to evaluate articles one by one. Each criterion for an article was assigned a score using a pre-defined scale (0~2). The given score was based on the description or hint provided by the article. The scoring results for criteria are shown in Table 2, column 4, 7, and 10. The

reasons for the given score are displayed in Table 2, column 6, 9, and 12. After obtaining every criterion's score, we multiply the original score by its corresponding global weight to obtain a weighted score. Every criterion's weighted score is calculated using the same way. The weighted scores of criteria for the three articles are shown in Table 2, column 5, 8, and 11. We interpreted the final normalized weighted score of an article as an impact indicator for its study results answering our research question, while the normalized un-weighted score of an article is just to show the study quality (methodological rigor and presentation). A higher un-weighted score of an article does not mean that its study result has higher impact on our study question.

3.2. Data Synthesis

All of the studied articles were neither randomized nor quasi-random studies, but were selected concurrent control studies, which had less methodological rigor [12, 18]. Welch et al. [6] chose four community physician practices in the same countries as study setting. Pollak&Lorch [5] selected three dialysis units from MIQS Inc. O'Connor et al. [11] selected practices from a Health Partners Medical Group. Drawing upon the evaluation results shown in Table 2, we find the Pollak &Lorch study has the highest normalized original score (0.800); the O'Connor et al. study ranks second, has score 0.600; the Welch et al. study ranks third, has score 0.560. The interpretation for these is that Pollak &Lorch has the best study presentation. However, when we see the normalized weighted score, the Pollak &Lorch study still has the highest score 0.558. But, the Welch et al. study has higher score than that of the O'Connor et al. study (0.478 vs. 0.474). We interpret this as that the Welch et al. study has slightly higher impact on our study goal when compare with the O'Connor et al. study because we only take evaluation criteria with respect to the research goal into account. Criteria for evaluating study presentation quality are not considered.

Regarding the impact of EHR on chronic disease management, the inferences are inconsistent when studied (see Table 3). O'Connor et al. argued that EMR use failed to achieve desirable levels of diabetes care improvement. However, Pollak&Lorch) reported that EPR could have a favorable effect on outcomes and cost in chronic disease management. Welch et al. concluded that EHR has a modest positive impact on the quality measure of guideline adherence for hypertension and hyperlipidemia but no significant impact for diabetes and coronary artery disease. No measurable impact on the short-term cost per episode was found.

3.3 Factors Associated with EHR Success

What are the factors associated with EHR success? O'Connor et al. suggested that improved implementation strategies and more sophisticated clinical decision support functions are needed. Pollak&Lorch argued that patient-centered and extensive coding are two crucial factors for EHR success. The patient-centered study EPR captures, stores, and retrieves on-line and without delay all patient-specific medical data from multiple information domains. Extensive coding is to display what has occurred over time, to evaluate and/or change the intervention and thus improve health care. Welch et al. believed that cultural and technology barriers are two major factors for successful EHR implementation.

4. CONCLUSIONS

We reviewed three controlled studies assessing the impact of EHR on chronic disease management. The primary findings are inconsistent. One study agreed that EHR had positive impact on chronic disease. Another argued that it lacks impact. The other concluded that the impact is partial, depends on the type of chronic disease. However, this study attempts to quantize the primary findings and provide a final conclusion to answer the study question. First, the primary study findings in Table 3 are scored on a 100-point scale. Next, we multiple each finding score by the corresponding study's normalized weighted score (impact indicator) in Table 2 to obtain a "weighted finding score". Finally, we sum all weighted finding scores and normalize it to have the final conclusion score 33.5 ((20*0.474+100*0.558+80*0.478)/3). Based on this score, we argue that EHR has 33.5% likelihood impact on chronic disease management.

There are three limitations for this study. One is that we only reviewed 13 published articles and selected 3 of them for analysis. The conclusion rigor is limited by the methods used in the primary studies. Moreover, the evaluation criteria for this study are a combination of three evaluation schemes. AHRQ [12] argued that

combining different schemes into a single evaluation framework risked misleading conclusions. Finally, the spectrum of EHR, EMR or EPR may be diverse. The study assumption of EHR is an alternative term for EMR and EPR may cause bias conclusion.

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Table 1: The evaluation criteria for the reviewed studies

Evaluation Criteria	Considered for analysis	Local Weight
A. Significance	**Yes**	**0.167**
1. Is the paper, and are its results, scientifically credible? (Yes=2, Unknown=1, No=0)	Yes	0. 315
	Yes	0. 204
2. Does the paper contain an increase in the scientific knowledge for the given topic? (Yes=2, Unknown=1, No=0)	Yes	0.192
3. Does the paper have a potential impact on patient care? (Yes=2, Unknown=1, No=0)	Yes	0. 289
4. Can the results be transferred to similar question or situations? (Yes=2, Unknown=1, No=0)	**Yes**	**0.833**
	No	-
B. Quality of scientific content	No	-
B1. General Criteria		
1. Is the number of the authors adequate for the content of the paper? (Yes=2, Unknown=1, No=0)	No	-
	No	-
2. Are any potential conflicts of interests indicated? (Yes=2, Unknown=1, No=0)	No	-
B2. Background and motivation	**No**	-
1. Is the relevance of the paper made clear? (Yes=2, Unknown=1, No=0)	No	-
B3. Purpose of the paper		
1. Are the aims of the paper and the research questions presented clearly? (Yes=2, Unknown=1, No=0)	**Yes**	**0.875**
	Yes	0.340
B4. Method and approach		
1. Allocation of study groups (random=2, quasi-random=1, selected concurrent controls= 0)	Yes	0.125
	Yes	0.778
2. Unit of the allocation (practice=2, physician=1, patient=0),		
3. Presence of baseline differences between the groups that were potentially linked to study outcomes (no baseline differences present or appropriate statistical adjustments made for differences=2, baseline differences present and no statistical adjustment made=1, baseline characteristics not reported=0)	Yes	0.317
4. The objectivity of the outcome (objective outcomes or subjective outcomes with blinded assessment=2, subjective outcomes with no blinding but clearly defined assessment criteria=1, subjective outcomes with blinding and poorly defined=0)	Yes	0.070
5. The completeness of follow-up for the appropriate unit of analysis (>90%=2, 80 to 90%=1, <80% or not described=0).	Yes	0.070
6. Scoring of analysis (absence or adjusted confounding factors with appropriate method=2, presence of partially adjusted confounding factors with appropriate method=1, presence of unadjusted confounding factors with questionable analytical method=0)	**No**	-
	No	-
B5. Presentation of results	No	-
1. Are the results presented clearly? (Yes=2, Unknown=1, No=0)		
2. Is it clear how, and from where the results have been derived? (Yes=2, Unknown=1, No=0)	No	-
	No	-
3. Negative data explained? (Yes=2, Unknown=1, No=0)	**No**	-
4. Limitation of study mentioned? (Yes=2, Unknown=1, No=0)	No	-
B6. Discussion	No	-
1. Is the discussion been formulated clearly? (Yes=2, Unknown=1, No=0)	No	-
2. Are facts, conclusions and opinions been separated? (Yes=2, Unknown=1, No=0)	No	-
	No	-
3. Is the significance of the result discussed? (Yes=2, Unknown=1, No=0)		
4. Has the generalization of the results been discussed? (Yes=2, Unknown=1, No=0)	**Yes**	**0.125**
	Yes	0.800
5. Have the implication of the results of the patient care or medical informatics research been discussed? (Yes=2, Unknown=1, No=0)	Yes	0.200
B7. Conclusions		
1. Can the conclusions really be derived from the presented results? (Yes=2, Unknown=1, No=0)		
2. Are the implications for future research or for patient care, discussed? (Yes=2, Unknown=1, No=0)		

Table 2: The primary study evaluation results

Evaluation Criteria	Considered for analysis	Global[1] Weight	O'Connor et al. (2005)			Pollak &Lorch (2007)			Welch et al. (2007)		
			Original Score	Weighted Score	Reasons	Original Score	Weighted Score	Reasons	Original Score	Weighted Score	Reasons
A.	**Yes**	**0.167**	-	-	-	-	-	-	-	-	-
A-1	Yes	0.053	2	0.106	hint	1	0.053	competing	2	0.106	high impact
A-2	Yes	0.034	0	0.000	hint	2	0.068	p13	1	0.034	not so much
A-3	Yes	0.032	2	0.064	hint	2	0.064	p9	0	0.000	No conclu.
A-4	Yes	0.048	0	0.000	hint	2	0.096	p1, 13	2	0.096	p326
B.	**Yes**	**0.833**	-	-	-	-	-	-	-	-	-
B1.	**No**	-	-	-	-	-	-	-	-	-	-
B1-1	No	-	2	-	hint	0	-	p13	2	-	p320
B1-2	No	-	0	-	hint	2	-	p13	0	-	no indicate
B2.	**No**	-	-	-	-	-	-	-	-	-	-
B2-1	No	-	2	-	hint	2	-	p1	2	-	p320~321
B3.	**No**	-	-	-	-	-	-	-	-	-	-
B3-1	No	-	2	-	p300	2	-	p1	2	-	p320
B4.	**Yes**	**0.729**	-	-	-	-	-	-	-	-	-
B4-1	Yes	0.248	0	0.000	p301	0	0.000	p1,2	0	0.000	p320
B4-2	Yes	0.088	2	0.176	hint	2	0.176	p1,9	2	0.176	p321
B4-3	Yes	0.057	1	0.057	hint	2	0.114	p7	0	0.000	hint
B4-4	Yes	0.232	1	0.232	hint	1	0.232	hint	1	0.232	p320~321
B4-5	Yes	0.052	0	0.000	hint	1	0.052	p7,8	0	0.000	no follow-up
B4-6	Yes	0.052	2	0.104	hint	1	0.052	hint	2	0.104	p326
B5.	**No**	-	-	-	-	-	-	-	-	-	-
B5-1	No	-	2	-	hint	2	-	hint	2	-	p324~325
B5-2	No	-	2	-	p303,304	2	-	hint	0	-	hint
B5-3	No	-	0	-	p303,304	0	-	p7,8	0	-	table4
B5-4	No	-	2	-	p305	2	-	p11	2	-	p326
B6.	**No**	-	-	-	-	-	-	-	-	-	-
B6-1	No	-	2	-	p304&305	2	-	p9,10	2	-	p326
B6-2	No	-	0	-	no conclu.	2	-	hint	0	-	hint
B6-3	No	-	0	-	P305	2	-	p7-9	0	-	hint
B6-4	No	-	0	-	P305	2	-	p7-9	0	-	hint
B6-5	No	-	2	-	hint	2	-	p7-9	2	-	p326~327
B7.	**Yes**	**0.104**	-	-	-	-	-	-	-	-	-
B7-1	Yes	0.083	2	0.166	hint	2	0.166	p10	2	0.166	p326
B7-2	Yes	0.021	2	0.042	hint	2	0.042	p12	2	0.042	p326
Normalized score			0.600 30/(25*2)	0.474 (0.947/2)		0.800 40/(25*2)	0.558 (1.115/2)		0.560 28/(25*2)	0.478 (0.956/2)	

Table 3: The primary study findings

Article	Impact on chronic disease management	Study findings
O'Connor et al. (2005)	Slightly (score = 20)	• EMR use led to an increased number of HbA1c and LDL tests but not to better metabolic control. • EMR use failed to achieve desirable levels of diabetes care improvement.
Pollak &Lorch (2007)	Yes (score = 100)	• EPR can have a favorable effect on outcomes and cost in chronic disease.
Welch et al. (2007)	More likely (score = 80)	• EHR had a modest positive impact on the quality measure of guideline adherence for hypertension and hyperlipidemia • EHR had no significant impact for diabetes and coronary artery disease. No measurable impact on the short-term cost per episode was found.

No=0, Slightly=20, Partial=40, More likely=80, Yes=100

[1] The global weight of a criterion is obtained by multiplying its local weight by its parent criterion's global weight.

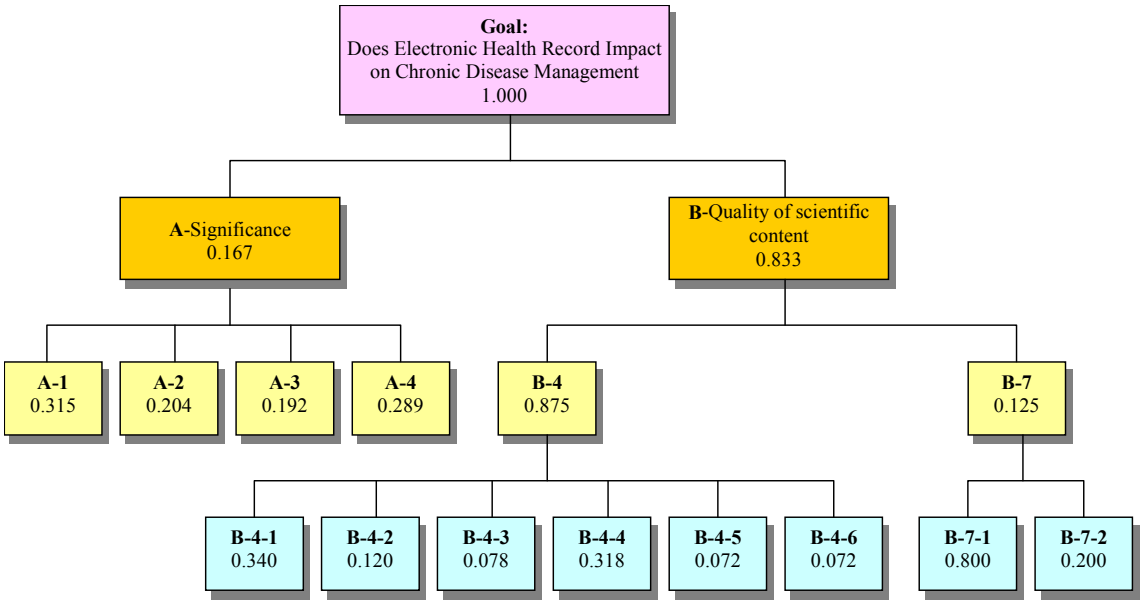

Figure 1: AHP hierarchy for the criterion weight decision, showing LOCAL priorities.

Criteria		More Important	Intensity
X	Y		
A	B	Y	5

(a). The judgment table

X \ Y	A	B
A	1	5
B	1/5	1

(b). The corresponding pairwise comparison matrix

Figure 2: The judgment table and corresponding pairwise comparison matrix for criterion A and B

Criteria		More Important	Intensity
X	Y		
A-1	A-2	X	1.5
A-1	A-3	X	2
A-1	A-4	=	1
A-2	A-3	Y	1.5
A-2	A-4	=	1
A-3	A-4	Y	2

(a). The judgment table

X \ Y	A-1	A-2	A-3	A-4
A-1	1	2/3	1/2	1
A-2	3/2	1	3/2	1
A-3	2	2/3	1	1/2
A-4	1	1	2	1

(b). The corresponding pairwise comparison matrix

Figure 3: The judgment table and corresponding pairwise comparison matrix for criterion A1~4

Criteria		More Important	Intensity
X	Y		
B4	B7	X	7

(a). The judgment table

X \ Y	B4	B7
B4	1	7
B7	1/7	1

(b). The corresponding pairwise comparison matrix

Figure 4: The judgment table and corresponding pairwise comparison matrix for criterion B4 and B7

Criteria		More Important	Intensity
X	Y		
B4-1	B4-2	X	3
B4-1	B4-3	X	4
B4-1	B4-4	=	1
B4-1	B4-5	X	5
B4-1	B4-6	X	5
B4-2	B4-3	X	1.5
B4-2	B4-4	Y	2
B4-2	B4-5	X	1.5
B4-2	B4-6	X	1.5
B4-3	B4-4	Y	4
B4-3	B4-5	X	1
B4-3	B4-6	=	1
B4-4	B4-5	X	5
B4-4	B4-6	X	5
B4-5	B4-6	=	1

(a). The judgment table

X \ Y	B4-1	B4-2	B4-3	B4-4	B4-5	B4-6
B4-1	1	3	4	1	5	5
B4-2	1/3	1	3/2	1/2	3/2	3/2
B4-3	1/4	2/3	1	1/4	1	1
B4-4	1	2	4	1	5	5
B4-5	1/5	2/3	1	1/5	1	1
B4-6	1/5	2/3	1	1/5	1	1

(b). The corresponding pairwise comparison matrix

Figure 5: The judgment table and corresponding pairwise comparison matrix for criterion B4-1~6

Criteria		More Important	Intensity
X	Y		
B7-1	B7-2	X	4

(a). The judgment table

X \ Y	B7-1	B7-2
B7-1	1	4
B7-2	1/4	1

(b). The corresponding pairwise comparison matrix

Figure 6: The judgment table and corresponding pairwise comparison matrix for criterion B7-1and B7-2