INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS 78 (2009) 127–140

journal homepage: www.intl.elsevierhealth.com/journals/ijmi

A PACS maturity model: A systematic meta-analytic review on maturation and evolvability of PACS in the hospital enterprise

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ARTICLE INFO

Article history:
Received 4 January 2008
Received in revised form
18 June 2008
Accepted 24 June 2008

Keywords:
PACS
Maturity
Evolvability
Alignment
Meta-analysis
Hospital enterprise

ABSTRACT

Introduction: With PACS and medical imaging technology maturing, the importance of organizational maturity and effective deployment of PACS in the hospital enterprise are becoming significant.

Objective: The objective of this paper is twofold. Firstly, PACS literature on maturity and evolvability in the hospital enterprise is analyzed, resulting in an overview of the relevant developments concerning maturity of PACS. Secondly, this paper looks at the development of a maturity model for PACS technology.

Methods and results: Using structured search queries, we identified 34 papers reporting relevant aspects of maturity and evolvability of PACS. From the results of a meta-analytic review on PACS maturity and evolvability, we propose a model – the PACS maturity model (PMM) – that describes five levels of PACS maturity and the corresponding process focus.

Conclusion: We argue that this model can help hospitals to gain insights into their (strategic) objectives for growth and maturity with regard to PACS, the electronic patient record (EPR) and other health information systems. Moreover, the proposed model can be applied as a valuable tool for organizational assessments, monitoring and benchmarking purposes. Hence, the PMM contributes to an integral alignment model for PACS technology.

1. Introduction

The field of healthcare and medical informatics has gradually evolved through a number of stages and established itself in recent years. The field is very broad and includes advances that have been made in medical imaging technology, e.g. picture archiving and communication systems (PACS), information systems, image-guided surgery and therapy, computer-aided diagnosis (CAD), decision-support systems and the electronic patient record (EPR) [1–3]. The field is still evolving although some claim that the area of PACS has matured and is no longer cutting-edge [4,5]. Others claim that PACS has been introduced into clinical practice too soon, and with too much hype, and research and development are very much in need now [6]. The utilization of the rapidly-growing results and possibilities of non-invasive digital imaging systems in clinical application, and related research and developing work, are also serious challenges [6,7]. Moreover, Hood and Scott [8] mention that to date there is little published information concerning the clinical impact of PACS in the working environment.

The concept of picture archiving and communication systems (PACS) was introduced as early as 1982 and after more than 20 years of research, development and implementations,

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doi:10.1016/j.ijmedinf.2008.06.010

PACS has become an integrated component of today's healthcare delivery system [9]. PACS can therefore be considered as the fundamental infrastructure for digital diagnostic imaging and information management systems. PACS originated as an image management system for improvement for the efficiency of radiology practice and evolved into a hospital-integrated system dealing with multimedial information. The integration of many different types of information requires the technology of multimedia: hardware platforms, information systems and databases, communication protocols, display technology and system interfacing and integration [10].

There are many definitions for PACS, ranging from simple IS/IT used for digitizing images to enterprise-wide image management systems and integrated workflow systems that streamline all operations throughout the whole patient-care delivery process. For instance, Huang [4] defines PACS as a workflow-integrated imaging system that is designed to streamline operations throughout the entire patient-care delivery process. Anderson and Flynn [11] did a systematic literature review of a broad range of topics about PACS. They defined PACS more from a technical point of view: picture archiving and communication systems (PACS) are high-speed, graphical, computer network systems for the storage, retrieval and display of radiological images. As the definitions indicate, PACS is a very broad term encompassing many related, but different, components and systems related to medical imaging for clinical practices [12]. PACS can thus be both very simple and be a more complex enterprise-wide system.

Although PACS is now a well-established technology, achieving a filmless environment with PACS is still a high-cost venture [13]. A successful method for implementing and aligning PACS in the hospital enterprise would therefore be a prerequisite, and insight into the current and desired level of maturity of PACS valuable to the hospital.

So, how can PACS maturity be modelled, measured and assessed, and what is known from current research on this fundamental topic in medical informatics?

Theories on information systems and information technology (IS/IT) maturity and adoption are well-established in business and IS/IT literature going back to the early 70s. The concept of the stage hypothesis was introduced by Nolan [14] in 1973, extended [15] and frequently discussed and adapted [16–20]. In general, the IS/IT maturity models provide insight into the structure of elements that represent process effectiveness of IS/IT in organizations [21].

In this research, we develop a model that can be used to assess the alignment and maturity of PACS, and PACS deployment performance within hospital enterprises. Since PACS is a system designed to streamline operations through the entire patient-care delivery system, one would expect that it makes a significant difference in terms of throughput and clinical action as well. It is suggested that theories on Business/IT-alignment, organizational fit and adoption of IS/IT can help us to understand why certain key elements in clinical practice have not been [22] achieved. In a first step to construct an integrative implementation/alignment framework for PACS, insight into the levels of maturity of PACS is a prerequisite. Next to the organizational aspects [23,24] the framework should enable the quantification of PACS maturity including its relation to PACS deployment performance. In this paper, we present the results of an extensive and systematic literature search that is performed in order to construct such a model that sets out PACS maturity and evolvability in the hospital enterprise.

To the best of our knowledge, we are the first in this as so far there is no reference to a recognized maturity model for PACS, and thus no valuable tool for empirical research.

1.1. *Outline of the paper*

The next section reviews the history of the PACS and sets out the relevant developments concerning IS/IT maturity and the maturity of hospital information systems. The method for our structured literature search is detailed in Section 3. Section 4 presents the review of maturity and evolvability of PACS literature and Section 5 proposes growth levels for PACS and a PACS maturity model based on a meta-analytic approach. Finally, we discuss both the opportunities and limitations of this study and the constructed PACS maturity model (Section 6).

2. Background

2.1. *PACS history*

The concept of a PACS was introduced more than two decades ago and the desire to store medical images digitally stems from well-known limitations in the film-based radiology departments [25]. The initial development of diagnostic imaging started over 50 years ago with the utilization of image-intensifier TV systems for fluoroscopy and the development of gamma camera for radionuclide imaging. Over the years much research has been done on electronic imaging, MRI, PET, SPECT, the development of computed tomography (CT), ultrasound imaging and PACS [26].

A PACS acquires medical images digitally from several modalities in the radiology department (e.g. CT, Ultrasound, MRI, plain X-ray), stores them in central data repositories/databases and makes them available upon request by, for instance, referring clinicians. Since the medical images are now in browser-based format, they can be made available for viewing almost instantaneously throughout the entire hospital and even beyond the boundaries of hospitals to off-site radiologists and other institutions using secure broadband internet connections.

Nowadays the PACS industry is a well-matured industry and offers archiving solutions and reading stations that fulfil the needs of the users [27]. The Integrating the Healthcare Enterprise [28] also provides hospitals with a solid framework that from a technical point of view ensures that different information systems – including HIS, RIS, EMR – are well integrated. PACS are deployed in most academic centres and many private practices are joining the ranks of the digital radiology revolution [5]. A recent survey on E-business in 2006 among 18 European countries, conducted by Empirica by order of the European Commission, posed the basic question for hospitals as to whether they use PACS or not. The (unweighted) result of this enquiry is presented in Fig. 1. Large differences between countries appear from these data. Only 10% of French