Categorizing Communication Errors in Integrated Hospital Information Systems

S. Saboor; E. Ammenwerth
Institute for Health Information Systems, UMIT, Hall in Tyrol, Austria

Keywords
Classification, HIS management, systems architecture, information system

Summary
Objectives: Hospital information systems (HIS) are the hospital's nervous system. The HIS are mostly grown over several years, dedicated to specific needs and comprise individual workarounds. Changes to such complex systems may cause a variety of different negative side-effects. In order to understand the nature of incorrect communication in integrated HIS, a concise structured categorization of common communication problems and their reasons is essential. The objective of this paper is to present such a categorization, its development and verification.
Methods: We used a combined approach for the development of the error categorization: We started with a qualitative content analysis on available literature in PubMed. In order to ensure the validity and completeness of the results, we chose the method of problem-centered expert interviews.
Results: The resulting categorization of communication problems is represented as a five-level hierarchy. It comprises 81 problems that are related to the electronic communication. Further, it contains in total 229 entries that are either the reasons of these problems or recommendation for avoiding the problems.
Conclusion: To our knowledge there is no similar summary that concisely summarizes common communication problems and also refers to their underlying reasons. Equivalent content is mostly published in experience reports that just concentrate on single aspects. We used the details of such references in order to compile our categorization – it thus can be regarded as an intersection of relevant experiences. The categorization can raise a basic awareness on potential problems and supports the understanding of the underlying reasons. An evaluation in a real environment must prove whether the content of the categorization is correct.

Correspondence to:
Samrend Saboor
University for Health Sciences, Medical Informatics and Technology (UMIT)
Eduard-Wallnöfer-Zentrum 1
6060 Hall in Tyrol
Austria
E-mail: Samrend.Saboor@umit.at

Methods Inf Med 2009; 48: 203–210
doi: 10.3414/ME9220
prepublished: February 18, 2009

1. Introduction

The main tasks of hospital information systems (HIS) are the processing and communication of required information between all involved actors and departments [1]. Commonly accepted definitions (e.g. [2]) refer to the HIS as the hospital's nervous system. Especially the electronic application systems of the HIS have gained importance within the last two decades [3] – amongst others, because of the increased amount and variety of data that has to be transmitted but also because of the shift from centralized to decentralized organizations of healthcare institutions.

This trend also emphasizes the great importance of the adequate communication for healthcare processes [4]. It is therefore necessary that the electronic application systems ensure the correct transmission of required information objects. For this purpose, all involved application systems must agree upon a common communication convention [5–7]. This convention is specific for the respective HIS. It includes specifications of the organization of information objects (e.g., as sets of identifier-attributes pairs), the definition of the meaning of each attribute and consequently detailed specifications regarding each application system's communication interfaces. It further must be stressed that current HIS are composed of a variety of specialized electronic sub-systems and application systems from different vendors – see for instance Dwyer's subdivision of a picture archiving and communication system (PACS) [8]. We therefore also refer to them as integrated HIS.

Established communication standards (i.e., DICOM (Digital Imaging and Communications in Medicine [9]) and HL7 (Health Level 7 [10])) shall ensure the integration of the different application systems. But even the usage of just one of the standards requires careful implementations [6, 7]. A main difficulty here is that standard definitions still allow misinterpretations – which leads to errors using just one of the standards (e.g. [11, 12]). Most integrated HIS however require the implementation and incorporation of several standards which comprises additional difficulties (e.g. [13–15]). Here, the coordinating framework of the international initiative for Integrating the Healthcare Enterprise (IHE) [16, 17] has clearly helped to improve the integration of application systems.

Nevertheless, integrated HIS are mostly grown architectures – for instance, acquisition modalities can be used up to 20 years which might make it necessary to integrate very old systems (e.g., VAX [18] or PDP-11

[19]). Thus, most integrated HIS comprise a variety of local workarounds which make the HIS's architecture unique and complex. The complexity aggravates the anticipation of negative side-effects in a reasonable amount of time.

In order to understand the nature of incorrect communication in integrated HIS, a concise structured collection of common communication problems and their reasons is essential. Such a collection still seems to be missing.

This paper describes the development and verification of a categorization that contains concrete communication problems, their reasons and recommendations for avoiding the problems.

2. Methods

The communication error categorization was developed in the following two main steps.

2.1 Inductive Collection of Common Communication Problems and their Reasons

In order to collect communication problems and their reasons, we chose the method of subsuming qualitative content analysis (according to Mayring [20, 21]. This type of content analysis aims to filter the main interesting details of the reviewed literature by the abstraction and dynamic declaration of categories. For this, we conducted a systematic review of the available literature in PubMed. Here, we made use of the experiences from earlier projects in the area of process assessment (e.g. [22]). The inductive approach that we chose is shown in ▶Figure 1.

First, an initial set of search phrases (e.g., "quality information processing") was declared according to the aim of the review. In steps three and four, the title and abstract of all the references that resulted from the search phrases were reviewed and ranked. In step five, we adjusted and augmented our search phrases according to the adequateness of the resulting references. In this way we found 4188 references. These references dealt with, among others, information management (e.g. [2]), reports on integration projects in the field of HIS, radiology information system (RIS) and PACS (e.g. [23, 24]). From this set we dropped all of those references that were older than 20 years, which dealt with the implementation of very specialized software development topics or with organizational issues. In the sixth step, we performed the actual qualitative content analyses on the remaining 426 references. In this step, further keywords were also found, which we used in step seven to adjust our set of search phrases. The process is stopped when the saturation of new errors is reached.

Relevant excerpts from the references were first collected in an unsorted list. During transcription, the formulations of similar entries were assimilated and grouped. In this way a categorization of communication problems and their reasons was created. Please see ▶Table 1 in Section 3.

2.2 Expert Interviews for Verification

We chose the method of problem-centered expert interviews in order to check the results of the literature analysis (i.e., the communication problems and their reasons). This step was performed in order to ensure that:

1. the developed categorization contained all relevant communication problems and that no important reason was missing;
2. the relationships between communication errors and reasons were correct.

We contacted experienced hospital information managers, integration engineers (i.e., software engineers specialized on the implementation of medical communication standards such as HL7 and DICOM) and members of working groups dealing with integration issues. All participating experts received an electronic copy of the error categorization. We asked them to review the categorization before the actual interview. For this purpose, we also provided a guideline that clarified the focus of the interview. The actual interview was mainly performed via telephone in an open semi-structured way.

The inclusion criteria for the selection of the experts were:

1. At least two years' (preferably five years) working experience in implementing clinical application systems that communicate via HL7 or DICOM.
2. At least two years' (preferably five years) working experience in administrating HIS, PACS or RIS databases (i.e., database

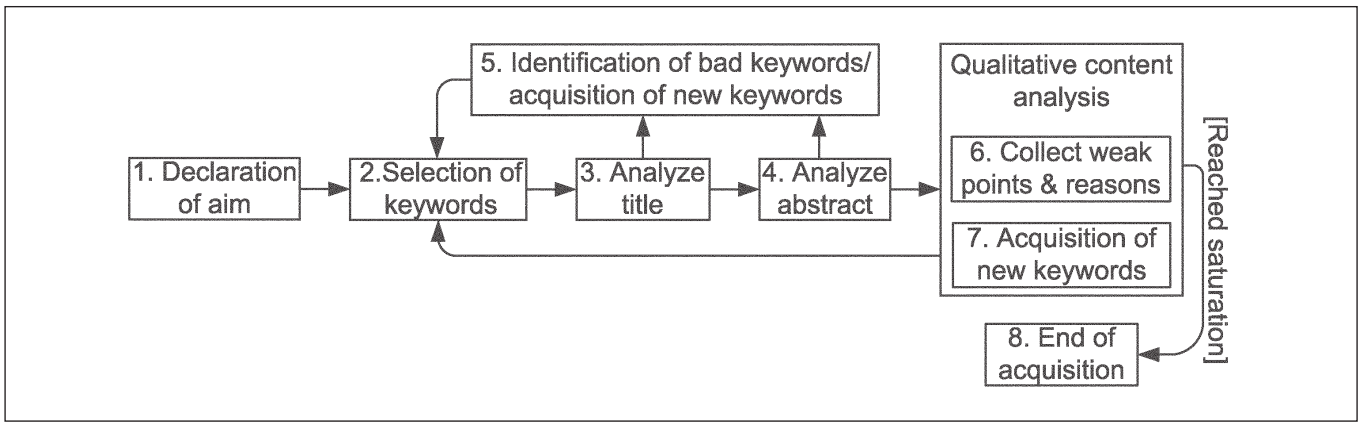

Fig. 1 Iterative literature review process – According to the review's aim, appropriate keywords are selected and references are searched iteratively. Adequate results are analyzed for communication problems and their respective reasons. The process stops after a saturation is observable.

is filled with data from HL7 and/or DICOM messages).
3. At least two years' (preferably five years) practical experience in projects introducing or updating clinical application systems that communicate via HL7 or DICOM.
4. At least two years' (preferably five years) practical experience in implementing IHE profiles.

In total, we invited 42 experts that met at least one of the mentioned criteria. Twenty-eight experts responded and were willing to review the categorization. In the end, 17 experts were actually interviewed:

- Twelve software developers with 3–15 years of working experience in implementing HL7 and DICOM applications. Three of the interviewed developers stated explicitly to have at least three years of practical experiences in implementing IHE profiles. Three developers are also working in standardization boards.
- One product manager of a health care company who supervises the development of new HL7 and DICOM applications and who is also responsible for integration issues for 10 years.
- Four project managers from hospitals and healthcare companies with 5–14 years of working experience in introducing or upgrading DICOM or HL7 infrastructures. One of them is also working for a national IHE board.

3. Results – A Categorization of Common Communication Problems

▶Table 1 shows the current version of the developed communication error categorization. It is organized in the following five hierarchy levels:

- The first and most abstract level is called "Aspect": It differentiates whether a problem concerns the information objects, their administration or their transfer between application systems.
- The second level is called "Detailed aspect": It differentiates the rough categorization of the first level according to more concrete aspects such as "Content" or "Ac-

Table 1 Excerpt of the categorization of communication errors (i.e., column "Problem")

Aspect (explanation)
Detailed Aspect (explanation)
Problem class (explanation)
Problem
I) (Series of) Information objects (errors which are related to single information objects or series of these)
I.1) Content (errors which are related to content problems)
I.1.a) Wrong details in data (errors dealing with wrong content)
Data entry error/Editing error
Redundant data entry
Wrong identification of information objects
Wrong details in data / Inaccurate details in information objects / Corruption of content
I.1.b) Missing data (errors dealing with incomplete information objects or incomplete series of information objects)
Missing identification of information object instances
Values of important attributes are missing
Missing information objects (in groups of interrelated information objects)
I.1.c) Incompatibility of content (errors dealing with incompatible content)
Incompatible value representation of data attributes
Content not machine-processable
Differences in data model
Incompatible data format / Differences in data format
Incompatible identification numbers
Incompatible messaging context
I.1.d) Semantic error (errors dealing with semantic ambiguity)
Semantic errors / Semantic ambiguity
Interpretation error
I.1.e) Bad quality of image or rest of content (errors dealing with bad imaging quality / bad quality of the content of information objects that is not stored in tags or attributes)
Overall bad image quality
Loss of data quality/image quality
Artefacts in digital image data
Overall wrong results
I.2) Acquisition and import (errors dealing with problems during acquisition and import)
I.2.a) Acquisition errors (errors dealing with acquisition problems)
Errors in provided/acquired attributes
Incomplete acquisition
Delay during import

Table 1 Continued

Aspect (explanation)
Detailed Aspect (explanation)
Problem class (explanation)
Problem
II) Data management (errors dealing with the management (database/management system) of information objects)
II.1) Access – Permissions and Security (errors dealing with the access on information objects / securing an information objects content)
II.1.a) Authorization problems (errors dealing with access restrictions)
Missing authorization
Deficient data security allows illegal access and possibly deletion
II.2) Access – Availability (errors dealing with the availability or access problems of information objects)
II.2.a) No access possible (errors dealing with availability problems of information objects)
Data not available
Distributed/remote access not possible
II.2.b) Problems in tracing information objects/locations (errors dealing with locating problems of information objects)
Tracking of information objects not possible or difficult
II.2.c) Insufficient accessing time (errors dealing with too slow accessing times)
Delay at/after acquisition
Slow availability of data
Slow access on storage media
Shortcoming in server connection
II.2.d) Concurrent access (errors dealing parallel accesses on information objects)
Concurring access
II.3) Storage (errors dealing with the storage of information objects)
II.3.a) Data loss (errors dealing with the loss of information objects)
Missing backup / Error correction
Routine deletion of data – archival-duration too short
Inappropriate access – Deletion by accident
Loss of data during acquisition
Data is not sorted correctly into managing system / Wrong data assignment
II.3.b) Storage problems (errors dealing with the storage of information objects/storage media)
Storage shortcoming
Loss of (portable) storage media
Deprecated storage media
Damaged storage/media
System failure

quisition and import". This level comprises 10 entries.

- The third level is called "Problem class": It groups similar concrete problems. For instance, the entry "Content" on the second level contains amongst others the classes "Wrong details in data" and "Missing data". The categorization contains 28 of these classes.
- The fourth level is called "Problem": It contains the 81 problems that resulted from the qualitative content analysis and the experts interviews.
- The fifth level is subdivided into "Reason" and "Recommendation": It contains reasons for the errors on level four along with recommendations that the authors gave in order to avoid those problems. This level comprises 229 entries.

Note: The columns "Reason" and "Recommendations" are independent although they are both assigned to the related entry in column "Problem". However, the inclusion of the content of these two columns would significantly increase the size of this paper. Therefore they are not included. In case of interest, please contact the authors for a copy of the full table. Some example entries for these two columns can be found in ▶Table 2.

4. Discussion

The electronic communication of information objects in hospitals requires an adequate integration of all involved electronic application systems in the HIS. In general, this requires that the application systems must transmit, store and process information objects without losing or deleting them, corrupting their structure or content or any other possible problem. However, most of the integrated HIS are historically grown architectures and therefore comprise a lot of individual workarounds. In consequence changes to their architecture may cause negative side-effects (although the existing HIS might work perfectly for most of the current purposes). The efficient anticipation of these problems is aggravated due to the aforementioned complexity. A main drawback in this context is that a summary of the distinct reasons for the possible problems is missing.

4.1 The Content of the Problem Categorization

The categorization that we are presenting in this paper is such a structured summary. To our knowledge there is no similar summary that concisely summarizes common communication problems and also refers to their underlying reasons. Also the IHE Technical Framework, although it can be regarded as the best practice of hospital application system integration, is not meant to name concrete problems and their reasons. The other contributions just focus on single aspects and are just meant to share the respective experiences – thus it is up to the reader to identify the essential details and to match the described setting with their own situation. For instance, Lian et al. describe in [25] the experiences they gained during their IHE project. Blado et al. deal in [26] with the possible causes of discrepancies between databases which lead to inconsistencies. In contrast, Kuzmak et al. write about wrongly selected worklist entries and the consequences [27]. König et al. describe shortcomings in the standard definitions and see them as reasons for possible integration difficulties [28]. We used the details of such references in order to compile our categorization – it thus can be regarded as an intersection of relevant experiences (see also Sections 2 and 4.2).

4.2 The Acquisition of the Problem Categorization

The problem categorization's details were acquired through a subsuming qualitative content analysis [21] on available literature that describes experiences regarding integration projects and the implementation of common communication standards (i.e., HL7 and DICOM). The qualitative approach strongly depends on the selected literature references and contains a certain degree of subjectivity (i.e., due to the subjectively selected search phrases). This can affect the validity and completeness of our categorization. In order to reduce subjectivity and to ensure that no valuable reference was overseen, the iterative process started with sensitive search phrases which were stepwise refined. Subsequent problem-centered expert interviews ensured the completeness and validity of the collected prob-

Table 1 Continued

Aspect (explanation)
Detailed Aspect (explanation)
Problem class (explanation)
Problem
II) Data management (errors dealing with the management (database/management system) of information objects)
II.4) Organization (all errors dealing with the structured sorting/organization information objects in archive/management system)
II.4.a) Assignment (errors dealing with the interrelation of information objects and their relations in hierarchies (in relation to patient/study-information)
Wrong / missing assignment of information objects to patient
Assignment errors of related information objects
II.4.b) Database alignment (errors dealing with the matching of different/separate databases)
Missing error notification
Not synchronized databases
Redundant data management
II.4.c) Database content errors (errors dealing with incorrect data in databases)
Redundancies in database content
Missing data cleansing
High latency failure correction
Missing version management
Uncoordinated data entry
Wrong data transmission
Leaking database integrity
Syntactic errors within database-entries
II.4.d) Completeness of database (errors dealing with incomplete databases)
Incomplete databases
II.4.e) Continuity of database (errors dealing with the continuity of databases)
Leaking continuity of stored data
III) Communication and Transfer (errors related to the transfer of information objects)
III.1) Application systems errors (errors dealing with application systems)
III.1.a) Insufficient support of services/Incompatible services (errors dealing with the services implemented by application systems)
Unsupported services
Insufficient information for services
Different communication interfaces
Incompatible service identification
III.1.b) Wrong communication content (errors dealing with the content of communications)
Unsupported content

Table 1 Continued

Aspect (explanation)
Detailed Aspect (explanation)
Problem class (explanation)
Problem
III) Communication and Transfer (errors related to the transfer of information objects)
III.1) Application systems errors (errors dealing with application systems)
III.1.c) Errors in the communication of information objects (errors dealing with the forwarding or processing of information objects)
Missing or incomplete processing rules
Stagnant processing
Communication disruption / Incomplete communication
Communication with wrong partner
No communication possible
No communication establishment
Requested system denies access or connection
III.1.e) Incompatible communication interfaces (errors dealing with the communication interfaces of application systems)
Too many different communication interfaces
III.1.f) Leaking availability of systems (errors dealing with the availability of application systems)
System is (temporarily) down
Blocked system
III.1.g) Instable software (errors dealing with the (software-)implementation of the application systems)
Unstable software versions
Software-Crash
III.2) Network (errors dealing with the (physical) network infrastructure)
III.2.a) Errors in infrastructure (errors dealing with the network)
Malfunctions of network
Network-infrastructure is not uniform
Insufficient degree of electronic communication
III.2.b) Insufficient capacities (errors dealing with capabilities of the network)
Insufficient network bandwidth
III.3) Transcription (errors dealing with the transcription of information objects)
Transcription error
III.3.a) Transcription errors (errors dealing with the transcription of information objects)
III.4) Security (errors dealing with the secure communication of information objects)
III.4.a) I,nsecure communication (errors dealing with securing communication links)
Violation of privacy policy
Insecure communication of critical contents

lems and reasons. Comments of the experts only pertained to some of the reason entries. But the categorization's structure and most of its content were accepted. This convinces us that our approach is adequate and sound. Of course an evaluation in a real environment must prove whether the content of the categorization is correct. But for this purpose, an adequate operationalization is necessary which is still an open issue (see also Section 4.4).

4.3 Anticipated Usage of the Categorization

The categorization can raise a basic awareness of potential problems (i.e., "What can go wrong? What should be considered?") and supports the understanding of the underlying reasons. Moreover, several of the interviewed experts suggested that the categorization could support the creation or completion of their Failure Mode and Effects Analysis (FMEA [29, 30]. This would apply to the hospital's information management as well as vendors of healthcare application systems. In the latter case, the mandatory standard ISO 13485 [31] provides a basic classification of possible risks that can arise for the patient due to errors of the respective application system. However, the matching between the standard risk classification and our problem categorization would require further efforts. As far as we know, no comparable mapping of problems on risk classes does currently exist.

4.4 Open Issues

The content of the categorization could be used for examining an entire communication process of interest for the occurrence of any of the collected problems (i.e., screening for potential problems). But there are currently some open issues that must be solved for that purpose:

The amount of the collected entries and their various interrelations make the categorization extensive. Especially in the current table-oriented form it only seems feasibly to use the categorization for looking up the reasons of specific problems. Also the current formulations of the reason and recommen-

Table 2 Excerpt of the categorization that also contains entries for the problem reasons (column "Reason") and recommendations in order to avoid the respective problem (column "Recommendation")

Aspect (explanation)			
Detailed Aspect (explanation)			
	Problem class (explanation)		
	Problem	Reason	Recommendation
I) (Series of) Information objects (errors which are related to single information objects or series of these)			
I.1) Content (errors which are related to content problems)			
	I.1.a) Wrong details in data (errors dealing with wrong content)		
	Data entry error/Editing error	Manual data entry; Too many entries in worklist / manual selection (ambiguous); Missing standardization of entry forms allows typos during manual entry; Combination of different independent details in one data field; Incompatible / foreign char-sets; Transformation of original content; Merge of (patient-)data	System provides suggestions for entry-fields according to database that fits the respective input; Usage of coded elements; Automated checks of manual data entry; Usage of automatically provided content, e.g. worklists, instead of manual data entry; Required data, e.g., for creation of new information objects, shall be retrieved automatically from sources with assured data quality; Usage of standardized tags/attributes instead of proprietary ones; Appropriate input-interfaces e.g. drop-down boxes rather than typing ; Replacement of accented letters with unaccented letters, conversion of all strings to upper/lower-case, replace punctuation signs with space, discard non-informative spaces
	I.1.c) Incompatibility of content (errors dealing with incompatible content)		
	Incompatible value representation of data attributes	Different data dictionaries – differences in representation and meaning of similar attributes; Different systems use different value lengths for representing/storing data values (stripping of content); Conversion error in communication standard – Lack in DICOM-Standard regarding combination of attribute length and value representation/value multiplicity; Incompatible character sets; Wrong implementation of application	Avoid usage of attributes with implicit value representation

dation entries still are too abstract and require background information for their correct understanding – i.e., a single entry comprises several underlying atomic aspects (e.g., the term "incompatible value representation" implies amongst others that at least two application systems are involved and exchange information. Further, each of the application systems uses a specific value representation. Consequently, an incompatibility exists if the involved systems use different value representations). Of course, breaking down the problem reasons results in even more details that must be considered. However, such a step helps to clarify which concrete details of the communication process are required for an adequate description. These details could then be used to support the correct data acquisition and to create a database. For each of the problems specific database queries could be developed on the basis of the already collected reason descriptions. Such an operationalization could also help to evaluate the problem categorization with examples from a real environment.

5. Conclusion

Understanding the reasons for errors in the electronic communication of integrated HIS is difficult. The complexity of most HIS aggravates an efficient anticipation of negative side-effects that might be caused by changes. A consolidated categorization of common communication problems and their underlying reasons is an essential prerequisite for solving this difficulty. This paper describes such a categorization and explains the combined qualitative process it was acquired with. In its current form, the categorization can raise a basic awareness on potential problems and helps to understand the underlying reasons. It can be used to look up the reasons for a specific problem of interest. Further it contains some recommendations the authors of the analyzed experience reports found useful for the avoidance of the respective problem. However, for screening an entire communication process for the occurrence of any of the communication errors an adequate operationalization is still required. It would then be possible to evaluate the categorization with communication processes from real environment.

References

1. Winter A, Brigl B, Wendt T. Modeling hospital information systems. Part 1: The revised three-layer graph-based meta model 3LGM2. Methods Inf Med 2003; 42 (5): 544–551.
2. Haux R, Winter A, Ammenwerth E, Brigl B. Strategic Information Management in Hospitals. New York, USA: Springer-Verlag; 2004.
3. Haux R. Health information systems – past, present, future. Int J Med Inform 2006; 75 (3–4): 268–281.
4. Coiera E. When conversation is better than computation. JAMIA 2000; 7 (3): 277–286.
5. Brazhnik O, Jones JF. Anatomy of data integration. J Biomed Inform 2007; 40 (3): 252–269.
6. Giuse DA, Kuhn KA. Health information systems challenges: the Heidelberg conference and the future. Int J Med Inform 2003; 69 (2–3): 105–114.
7. Kun L. Interoperability: the cure for what ails us. IEEE Eng Med Biol Mag 2007; 26 (1): 87–90.
8. Dwyer S. A personalized view of the history of PACS in the USA. In: Blaine G, Siegel E, editors. Proceedings of the SPIE: Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues; 2000; San Diego, CA, USA; 2000. pp 2–9.
9. ACR/NEMA. DICOM Homepage. 2008 (cited Sep 2008). Available from: http://medical.nema.org
10. HL7. Health Level 7. 2008 (cited Sep 2008). Available from: http://hl7.org
11. Gross-Fengels W, Miedeck C, Siemens P, Appel R, Muckner K, Finsterbusch J, et al. PACS: from project to reality. Report of experiences on full digitalisation of the radiology department of a major hospital. Radiologe 2002; 42 (2): 119–124.
12. Matthews JW, Bosch WR. Explicit-VR transfer syntax limits the value multiplicity of DICOM data elements with decimal string (DS) value representation. Phys Med Biol 2006; 51 (5): L11–2.
13. Hammond KW, Helbig ST, Benson CC, Brathwaite-Sketoe BM. Are electronic medical records trustworthy? Observations on copying, pasting and duplication. AMIA Annu Symp Proc 2003. pp 269–273.
14. Khorasani R. Medical management: expanding radiologists' role using information technology to improve the quality of care. Semin Roentgenol 2003; 38 (3): 282–286.
15. Nissen-Meyer S, Holzknecht N, Wieser B, Francke M, Küttner B, Adelhard K, et al. Produktivitätsverbesserung durch klinikweite RIS und PACS: eine Fallstudie. Der Radiologe 2002; 42: 351–360.
16. HIMMS/RSNA. IHE – changing the way healthcare connects. 2008 (cited Sep 2008). Available from: http://www.ihe.net
17. Mildenberger P, Wein B, Bursig HP, Eichelberg M. Current developments in DICOM and IHE. Radiologe 2005; 45 (8): 682–689.
18. Marlow SP, Mackenzie DA, Tomlinson JB. PC/VAX or standalone PC-based general purpose biological data collection system. Med Biol Eng Comput 1993; 31 (1): 22–30.
19. Sieving A, Billquist J, Smith R, Müller D. The PDP-11 FAQ. Technical report, Usenet, 2000 (cited Sep 2008). Available from: http://www.village.org/pdp11/faq.html
20. Mayring P. Einführung in die qualitative Sozialforschung: eine Anleitung zu qualitativem Denken. 5th revised edition. Weinheim: Beltz, Psychologie-Verl.-Union; 2002.
21. Mayring P. Qualitative Inhaltsanalyse – Grundlagen und Technik. 8th edition. Weinheim und Basel: UTB; 2003.
22. Saboor S, Chimiak-Opoka J, Ammenwerth E. Supporting the Systematic Assessment of Clinical Processes: the MedFlow Method. Methods Inf Med 2007; 46 (5): 586–594.
23. Kotter E, Langer M. Integrating HIS-RIS-PACS: the Freiburg experience. Eur Radiol 1998; 8 (9): 1707–1718.
24. Mongkolwat P, Bhalodia P, Gehl JA, Channin DS. Validating DICOM content in a remote storage model. J Digit Imaging 2005; 18 (1): 37–41.
25. Lian JD, Lin IC, Wu HC. Case report: Taiwan's experience in adopting IHE technical framework to integrate systems. Stud Health Technol Inform 2006; 122: 877.
26. Blado ME, Tomlinson A. Monitoring the accuracy of a PACS image database. J Digit Imaging 2002; 15 (Suppl 1): 87–95.
27. Kuzmak PM, Dayhoff RE. Minimizing Digital Imaging and Communications in Medicine (DICOM) Modality Worklist patient/study selection errors. J Digit Imaging 2001; 14 (2 Suppl 1): 153–157.
28. König H, Klose KJ. Modelling of radiological services in the context of a hospital information system: does the DICOM standard meet the requirements? Radiologe 1998; 38 (10): 872–882.
29. Spath PL. Using failure mode and effects analysis to improve patient safety. Aorn J 2003; 78 (1): 16–37; quiz 41–4.
30. Stalhandske E, DeRosier J, Patail B, Gosbee J. How to make the most of failure mode and effect analysis. Biomed Instrum Technol 2003; 37 (2): 96–102.
31. ISO. ISO 13485:2003 – Medical devices – Quality management systems – Requirements for regulatory purposes. 2008 (cited Sep 2008). Available from: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber= 36786

