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REVIEW

# A Design Protocol to Develop Radiology Dashboards

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**ABSTRACT**

**Aim:** The main objective of this descriptive and development research was to introduce a design protocol to develop radiology dashboards. **Material and methods:** The first step was to determine key performance indicators for radiology department. The second step was to determine required infrastructure for implementation of radiology dashboards. Infrastructure was extracted from both data and technology perspectives. The third step was to determine main features of the radiology dashboards. The fourth step was to determine the key criteria for evaluating the dashboards. In all these steps, non-probability sampling methods including convenience and purposive were employed and sample size determined based on a persuasion model. **Results:** Results showed that there are 92 KPIs, 10 main features for designing dashboards and 53 key criteria for dashboards evaluation. As well as, a Prototype of radiology management dashboards in four aspects including services, clients, personnel and cost-income were implemented and evaluated. Applying such dashboards could help managers to enhance performance, productivity and quality of services in radiology department.

**Key words: Dashboards; Protocol; Radiology Department; Design;**

## 1. INTRODUCTION

The field of radiology is continuously growing. Since imaging services are widely used and affect on patient care in the hospital, much attention has been paid to quality assurance in radiology departments. Since, measuring the quality of imaging services is inherently difficult, standard sets of KPIs should be used as key tools for evaluating and improving departmental processes. In traditional method, the monitoring of indicators involved the review of patient records to document the effect of diagnostic imaging on the care outcome is costly in staff time and labor (1).

With the modernization of radiology departments, along with using electronic information systems such as PACS, RIS, speech recognition systems, preliminary report systems, hospital information systems, and electronic health records, workflow and informatics infrastructure supporting them became very complex. This is because it requires combining many computerized systems with different user environments to provide quality efficient services in less time (2-3).

Since within this complexity, close monitoring the operational and financial data is an essential element for the management; Traditional methods of data involving review of Key Performance Indicators become quickly outdated and changed to use new technologies. In recent year, a variety of management tools have been introduced to digitally monitor essential data under the general name of dashboards (4).

Dashboards is an intellectual and visual tool for monitoring of KPI which can capture key data from different systems and represent them summarized and useful in real-time with easier reading and interpretation for users (5). This business intelligence tool can applied in radiology department as used in other sections such as operation rooms (6), emergency rooms (7), diabetes (8), and hospital infection control (9).

In radiology department, workflow are optimized when radiologists have real-time information to make informed decisions, and the capacity to efficiently act on that information. Dashboards technology can facilitate informed, optimized decisions about workflow by link directly to the electronic information systems and provide the right information in a right format at the right time to monitor productivity in order to improve in performance and effectiveness of activity (10). In this research, a design protocol to develop radiology dashboards in order to enhance performance, productivity and quality of services in this department, has been proposed. As well, a prototype of radiology management dashboards were implemented and evaluated using data obtained from a selected hospital affiliated to Tehran University of Medical Sciences.

## 2. RESEARCH METHOD

This descriptive and development research has been done in 4 steps during 2012 up to 2014.

**Determine Key Performance Indicators for radiology department:** This descriptive study was conducted using the Delphi technique. In this step, study population was including 30 radiologists who were members of Iranian Radiology Association and had professional experience in managing of radiology department. Non-probability sampling method including convenience and purposive were employed. Electronic questionnaire was used to collect information. At the end of the two-stage Delphi technique 92 key indicators to assess the performance of the radiology department into 7 main categories including "safety, service, internal and external customers, teaching and research, resource utilization, financial performance and excellence in the workplace" was determined.

| Group | | Key Performance Indicators |
|---|---|---|
| Patient safety | | Patient identification error rate, Site identification error rate, Side identification error rate, Procedure selection error rate, Specimen labeling error rate, Image labeling error rate, Protocol selection error rate, Critical test reporting rate, Critical results reporting rate, Error rate of image interpretation, Medication error rate, Medication allergy rate, Adverse drug reactions rate, Failure rate of electronic information transfer rate, Order entry error rate, Hazard related to environment rate, Hazard related to equipment rate, Intravenous extravasations rate, Radiologic-induced pneumothorax rate, Skin Impairment rate, Post-procedure hematomas rate, Contrast-media reactions rate, Contrast material-induced nephropathy rate, Radiologic-induced infection rate, Improper dose rate, Patient falls with harm rate |
| Radiology Services | | Examinations ordered but not performed, Examination completed but not interpreted, Examination volume, Examination volume per modality, Repeat/reject rates, Image turnaround time, Report accuracy rate, Report Dictated but not signed, Report turnaround time, Radiology/ pathology report correlation, Radiology/ ultrasound report correlation, Rat of Images no sent, Rate of network disruption, Rate of work interruptions in PACS, Appointment Availability, Sample delivery times to pathology laboratory, Patient wait time |
| Internal and external customers | | Number of Patient Complaints, Number of Referring Physician Complaints, Number of Employee Complaints, Proportion of patients referred from the Institute (Internal) to patients referred from other centers (external), Percentage or proportion of referrals from neighboring city or provinces |
| Teaching and research | Research | Amount of funding received, Contribution rate of radiology department resources to research, Number of publications in journals, Number of presentations delivered internally and externally, Number of patents |
| | teaching | Number of residents/fellows, Ratio of number of residents to number of faculty members, Ratio of number of fellowships to number of faculty members, Ratio of number of patients to number of residents /fellowships, Number of courses or training sessions requested and delivered, Number of training seats available, Access rate to internet and modern literature, including books and articles |
| Resource utilization | Radiology equipment | Average age (in months) of major imaging systems, Number of late-generation imaging devices, Variance in number of hours of scheduled maintenance from manufacturer recommendations, Percentage of time when equipment is unavailable, Ratio of number of hours available to number of hours in use |
| | Radiology Staff | Ratio of number of technician to number of machines, Number of reports generated per radiologist, Number of examinations performed per technician, Ratio of number of patients to number of admissions staff, Number of reports generated per typist, The number of medical physicists, Number of Radiologists with subspecialty qualifications |
| Financial performance | revenue | Measure of total amount billed, Measure of total amount reimbursed |
| | Expenses | Total costs of salary and benefits, Measure of costs per examinations performed, Total costs of equipment (purchase, installation and maintenance), Total cost of expendable, Total amount of bills rejected by insurers, Total amount of benefits paid to each employee as a fee for service, Total costs of advertising |
| | Financial productivity | Ratio of total labor costs (salary, benefits, and contract labor) to total revenue, Net operating margin |
| Excellence at workplace | | Number of reported incidents, Numbers of courses and training programs offered, Percentage of staff participating in training course, Average overtime hours worked (per employee), Average working hours of radiologist at the Institute during the day, Average working hours of technicians the Institute during the day, Number of radiologists and/or technologists working in the regional, national or international scientific or professional positions, Number of awards distributed, Total amount of pay incentives disbursed for excellent performance |

Table 1. *Key performance indicators in radiology department*

**Determine a comprehensive model for designing of dashboards:** This step of the research is descriptive. The study population was composed of 15 specialists in the field of informatics who had experience in creating dashboards. Non-probability sampling method including convenience and purposive were employed. Electronic questionnaire was used to collect information. At the end of this stage, 10 main features including" determining the goal of dashboards design, aligning with organizational goals, determining KPIs, setting a time frame, extracting the accurate data, flexibility, drilling-down capabilities, security, how to representation and display alert" were determined as a model for designing dashboards.

**Determine required infrastructure for implementation of Radiology Management Dashboards:** Infrastructure was extracted from both data and technology perspectives and the following steps are performed:

- Determining the goals of the dashboards design in order to determine the KPIs
- Defining the target group who are authorized to use dashboards
- Determining whether the dashboards show the retrospective data or real-time data?
- Determining KPIs to achieve defined goals and how to calculate them
- Identifying the required data to achieve these indicators and sources of data
- Setting intervals to update the information
- Identifying the reporting format of the data resource
- Specifying how to extract data

**Determine the key criteria for assessing the dashboards:** In this step, a total of 46 specialists from medical informatics, health information management, software engineering, and radiology field who had experience in the field of business intelligence were chosen as study population. Non-probability sampling method including convenience and purposive were employed. Electronic questionnaire was used to collect information. At the end of this stage, 53 key criteria in seven categories including "user-customization, knowledge discovery, security, information delivery, visual design, alerts, connectivity and integration" were determined for dashboards evaluation.

## 3. RESULTS

The findings based on the research steps are the following: In first step, as shown in Table (1), 92 key indicators to as-

| Description | Attribute |
|---|---|
| Determining the goal of dashboards to achieve defined goals and how to calculate them | Determining the goal of dashboards design |
| Design of dashboards aligning with organizational goals and objectives | Aligning with organizational goals |
| Determine the indicators which are critical and special to the quality of their performance along with their calculation method and threshold | Determining key performance indicators |
| Set the time interval for updating information based on users' view, type of use, and importance of task | Setting a time frame |
| Extract accurate and relevant data with acceptable and standard definitions in order to calculate | Extracting the accurate data |
| Capability to optimization, customization based on requirement of users, organization and changing in circumstances | Flexibility |
| User's ability to perform in-depth analysis by clicking on the operational indicators | Drilling-down & analyzing capabilities |
| procedures, techniques and technologies used to protect data | Security |
| Consider components of visual design, structure, layout and presentation of information | How to representation |
| A mechanism to highlight the important information such as exceptions, and outliers | Display alert |

Table 2. *A Comprehensive Model for Designing Radiology Dashboards*

| Selected KPIs for dashboards | Description |
|---|---|
| Number of services | Total number of services, number of services per modality in month |
| Number of clients | Total number of inpatient clients per modality, Total number of outpatient clients per modality, Total number of clients per modality in month |
| Number of days off | The number of days that employees were not present in the radiology department. |
| Number of training hours | The number of hours spent on training courses for the staff in the radiology department |
| Number of staff | Number of staff based on field and organizational status |
| Number of complaints | Number of patient complaints about radiology department, Number of complaints based on reason |
| Revenue | Inpatient revenue, Outpatient revenue , Revenues per modality |
| Costs | The costs related to requirements, salaries, maintenance purchase, installation and maintenance of machines, fee for service |

Table 3. *Selected KPIs for radiology department management dashboards*

sess the performance of the radiology department at the seven categories were determined. In the second step, a comprehensive model for the design of the dashboards as shown in Table (2) was determined. In the third step, to prepare prototype radiology management of dashboards, QlikView software as open source integration software that is executable in a hospital operating systems including Windows XP, Windows 7 and Windows 8 are from Microsoft, was used. As well as, some KPI as shown in table (3) was selected from table (1) to display in radiology management dashboards, the data was captured form radiology information system, financial information system and personnel information system and the time interval for updating was monthly. In the fourth step, the dashboards evaluation criteria were determined which are presented in Tables 1-4 (4).

| GROUP | KEY CRITERIA |
|---|---|
| Easy Customization | Define goal and objectives, Define metrics, Set end-state target, Estimate and test correlation among metrics , Restricted access to specific metrics by different users, Assigning a group of users to a group of dashboards, Attach comments to metrics, Discussion forum among users, Change calculations |
| Knowledge discovery | Drill-down features, Dimensional modeling with hierarchies and levels, Dependency analysis, What-if analysis, Move from monitoring layer to analysis layer |
| Security | Appropriate authentication and authorization methods, Backup and restore procedures, version control Dashboards, Audit trails, Protecting data from change, Defining role-based security, Automatic accessibility change by change in user roles or groups |
| Information delivery | Reasonable response time and latency, Customized layout of metrics for print, Exporting information to spreadsheets, presentation slides, word, PDF, etc, Data filtering for selected reports, Sorting the report, Inserting/deleting columns, Scheduling automatic reports, Updating the reports |
| Visual Design | Visual intelligence to highlight areas and values, Table and chart on same screen, Toggling between tabular and chart views, Resizing, maximize/minimize, re-ordering of zones, Allowing different layouts, Inclusion of metric definition and calculation, Linking objectives with metrics, Linking metrics together, Having Metadata and help, Single screen with no scrolling |
| Alerts | Defining the alerts, Highlighting by color coding, Determining the timing of alerts, Placing the alerts in context, Customizing and managing the alerts, Delivering alerts through Dashboards website, Email or pager, Showing the next step, Explaining the problem using text |
| System connectivity & integration | Connectivity to a variety of data sources , Supporting different operating systems, Integrating with portals, Integrating with other applications, Recovering from software or hardware crash Integrating with programmatic APIs for data & metadata |

Table 4. *key criteria for the dashboards evaluation*

## 4. DISCUSSION

Given the above it can be concluded that the field of radiology is faced with the challenges of increasing service use, declining reimbursements, and staff shortages. In such an economically challenging environment, it becomes crucial for radiology departments to monitor their performance so that they can provide a high quality of services while staying within operational boundaries (11). Accordingly, in this research, enhancement of performance, productivity and quality of services in radiology department as the aims of dashboards designing was considered.

In this field, Performance improvement is a process that differs from analyses made in commercial companies, where increased revenue is the major goal. In healthcare, the benefit to the individual patient is the main goal, with less emphasis being placed on economic implications (12). So to improve the quality required to ensure the proper planning done. A key element to planning is to select required data, and then adopt appropriate methods to collect data actively, consistently and effectively and represent them in performance indicator format (13).

Therefore it is necessary to instill a culture to determine necessary data to calculate the KPIs, the ways to collect these data and appropriate tools should be used for data analysis and trending. However, it should be noted that quality is not a goal at the radiology department but it is responsibility and accountability of and necessary to create a shared vision by hospital and radiology practice leadership that centers on patient.

About Dashboards design, because of radiology department is complex environment and has a variety of services, clients, personnel, equipment, technologies, data and information which are generated, the following key points need to be considered:

**Organizational Culture:** Organizational culture is the normal behaviors dominating an organization (14) and can be an important factor in successful implementation of technology(15). Implementing dashboards requires organizational culture to accept objective data as the basis for decision making (6).

**Determining the goal of dashboards design:** Experts believe that dashboards objectives should be limited in order for the managers to allocate the resources to critical issues (16) and divide the objectives into three groups: financial, operational and quality (17). Therefore, the goals of dashboards design for the department should be clear; whether it is for workflow consolidation, workload distribution, urgency evaluation (18), capacity and workflow management (19), surveillance (20, 21), or financial reporting (22).

**Involving users:** in designing a comprehensive dashboards, it is necessary to involve users in the design and development processes because expectations will closely match to functionality and users provide suggestions based on their needs which can reduce the time of development and dashboards redesign after implementation as feedbacks and evaluations are provided (8, 15).

**Aligning with organizational goals:** Dashboards should be designed based on overall goals and objectives of organization in such a way that each department by monitoring its KPIs facilitates achieving its objectives besides the strategic goals of organization (1, 6, 8, 16, 23, 24, 25).

**Determining KPIs and benchmark standards:** Selecting the type of indicators which should be included in dashboards is important. Depending on its situation, each department needs to measure the indicators related to its own area of performance, not all the indicators (9, 26), in other words, indicators which are critical and special to the quality of their performance (27). Each indicator is selected according to business purpose and the ability to be gathered easily through standard business functions (28) and besides accurate measurement of the indicator (9), we should identify dashboards metrics from regulatory standards which we need for accreditation or credentials (29). In designing an effective dashboards, the number of measurements should be limited, at least 15 to 25, in order to be viewed at a glance (17).

**Data:** A well designed dashboards should include accurate data which is related to business process from different sources and based on acceptable and standard definitions in order to be used in benchmarking process (30). In addition, data storage should be based on standard format and coding to be able to manipulate them easily, to facilitate sharing them, and reduce their processing time while updating and querying from dashboards (20).

**Knowledge discovery:** It is necessary that the structure of data storage be in a logical hierarchy and with required granularity (6) for data mining (30) and online analytical processing (OLAP) (31) in order to extract knowledge from the data in dashboards. This will enable the user to drill down data with clicking on operational indicator to gain deep analysis of that indicator to prospectively predict the effects of decisions (6, 32-33) and preparing the reports in the form of pdf and Excel (31). Regarding knowledge extraction, considering the time of search, number of clicks, and the precision and accuracy of data are critical (8).

**Flexibility:** According to (18) dashboards should have the ability to be optimized, customized, workflow- integrated, and context-specified. This feature is also important for determining indicators such that the user can have access to the information for specific purposes(17) and can organize them according to his or her preferences and save them to reuse in future(34). In designing dashboards it is also important that dashboards would have the capability to add required metrics or make change in it (26, 29).

**Security:** It is important to make sure about the security of data at all times because in radiology department, dashboards data is the result of integration of a number of information systems and also based on the internet or intranet. According to (33) it is necessary to consider a unique accession number for connecting data parts together and a secure log-in to have access to pages containing personal health information. In addition, utilizing 'single sign -on' technology for the user to have access to each application is suggested (3, 34).

**Time frame:** The frequency of measurement of indicators depends on the nature of indicator and its effectiveness and importance on operation of department. The focus of measurement should change from period to period (9). Updating information based on users' view, type of use, and importance of task can be from every second to every month.

**Representation:** Since dashboards is a tool for quick, brief, and real-time representation of data, organizing and displaying data should be such that it could be easily read and interpreted (35) and the user does not need to scroll the pages (20). Depending on the type of indicators and their numbers, we can use tables or graphs to display for users to understand and make decisions (30). It is better to provide visualization in the form of graphs according to the type of indicator (36) to show benchmarking comparison (34) because tables cannot be easily and quickly read (36). What is critical is that the direct representation should be able to alert by color coding to show levels of threats. These alerts are based on performance target thresholds which are derived from the yearly goals and objectives (33). According to (3) user interface dashboards in radiology department should be divided into three groups: User, Division, and System. They can be represented in different colors based on the priority of alerts like the traffic light (a red, yellow, or green circle) (3, 9, 19, 33, 37).

**Dashboards Assessment:** assessment should be considered based on two aspects. One is the verification of dashboards and other side is evaluation of dashboards itself to find out its effect on the department performance which can be done through questionnaires given to users(32). The results can be

published in the form of newsletter in order for the users to make a general evaluation of their own and the department's performance over time (25, 37).

About dashboards implementation, for achieve to a comprehensive set of dashboards that contain managerial and clinical operations of the radiology department So as to be able to create the accountability and strategic value in all aspects of financial, quality and clinical, the following technical infrastructure is necessary to be considered:

- Designing data warehouse for gathering data from a variety of systems such as clinical information system and financial information system in order to get a comprehensive view of operations (34)
- Using back-end algorithm of indicators or statistics for providing general and detailed reports (20)
- Accessibility to Internet or Intranet in order to facilitate sharing data and maintain data dynamism (6, 31, 34)
- Utilizing SOA architecture to encapsulate data in middle ware layer to be of use in different systems (3)
- Using API to create a hyperlink in dashboards alert to load a study when clicked by the user (3)
- Using relational database with a web service interface for modifying and querying state (3)
- Utilizing interoperability standards such as HL7 messaging standards and DICOM to make connections and data exchange among different systems (3, 33)
- Using agents in data models for registering and managing alerts if alerts are to be shown in groups or individual (3)
- Designing dashboards in .Net environment because it will result in flexibility, ease and integration with the system (31, 34)
- Utilizing web based interfaces for visualizing information (33)
- Displaying graphics using server based web control which is much faster than the client based control (34)

## 5. CONCLUSION

In this research, the key performance indicators were determined in order to performance assessment of academic radiology departments. On top of this, a comprehensive model for designing of dashboards and a checklist including key criteria for assessing of dashboards were provided. It should be noted that the model and assessment checklist could be used for all types of dashboards.

Finally a prototype of radiology management dashboards was implemented in four aspects including services, clients, personnel and cost-income. Applying such dashboards could help managers to evaluate radiology department from desirable or undesirable stance of performance, resource consumption and distribution of manpower at a glance, as well as identifying problems, root cause analysis and solving them using valid information driven from dashboards. In addition, it allows enhancing performance, productivity and quality of services in radiology department.

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**CONFLICT OF INTEREST: NONE DECLARED.**

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