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Picture, Archiving and Communication System in the Italian NHS: A Primer on Diffusion and Evaluation Analysis

Luca Buccoliero,[1] Stefano Calciolari,[1] Marta Marsilio,[1] and Elisa Mattavelli[2]

This contribution focuses on picture archiving and communication systems (PACS) in the Italian National Healthcare System (NHS). It finally aims to test the Chiefs Radiology Department's perceptions about PACS along the main evaluation dimensions emerging from the literature. First, a brief review of the main literature concerning PACS evaluation leads the authors to classify the different approaches undertaken and highlight the main variables of investigation. Second, the evidence emerging from a survey is presented and discussed in the light of the literature review. The survey aims to: (a) map out the degree of PACSs diffusion and their main features in the Italian NHS; (b) verify whether and how PACS impact the dimensions analyzed in many evaluation studies carried out to date; (c) test the relationship between some measured impacts and specific PACS features.

KEY WORDS: Cost-benefit analysis, PACS integration, PACS implementation, PACS

Picture archiving and communication system (PACS) technology is becoming increasingly widespread in the field of diagnostic imaging in Europe,[1] the United States,[2] and Japan[3–5].

Since the 1984 annual meeting of the Radiological Society of North America (RSNA)—where the first PACS was showed to the world—there has not been unanimous consensus about the convenience of the new technology compared to the traditional analog one. Indeed, at a time when healthcare systems are striving to contain expenditure and facing a growing demand for higher level of service delivery, the economic burden of any innovation represents a crucial aspect for the decision maker. However, the literature is not consistent with the approaches and results concerning the benefits of this technology. Consequently, the situation may lead to the general perception that PACS have certain significant cost without evident benefits.

This contribution focuses on the Italian National Healthcare System (NHS), where the first PACS was implemented in the Hospital of Cattinara (Trieste) in 1988. It finally aims to test the Chiefs Radiology Department's perceptions about PACS along the main evaluation dimensions emerging from the literature.

First, a brief review of the main literature concerning PACS evaluation leads the authors to classify the different approaches undertaken and highlight the main variables of investigation. Second, the evidence emerging from a survey is presented and discussed in the light of the literature review. The survey aimed to: (a) map out the degree of PACSs diffusion and their main features in the Italian NHS; (b) verify whether and how PACS impact the dimensions analyzed in many evaluation studies carried out to date; (c) test the relationship between some impacts and specific PACS features.

[1]*From the Centre for Research in Health and Social Care Management, CERGAS-Bocconi University and Public Management and Policy Department, SDA Bocconi School of Management, Via Bocconi, 8 20136 Milano, Italy.*

[2]*From the SDA Bocconi School of Management, Milano, Italy.*

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Correspondence to: Luca Buccoliero, Centre for Research in Health and Social Care Management, CERGAS-Bocconi University and Public Management and Policy Department, SDA Bocconi School of Management, Via Bocconi, 8 20136 Milano, Italy; tel: +39-025-8362590; fax: +39-025-8363593; e-mail: luca.buccoliero @unibocconi.it

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BACKGROUND

The challenge in defining systematic methodologies and methods for the evaluation of digital image management systems adopted by hospitals led several authors[6] to define PACS as "difficult to evaluate" technologies. The complexity mainly belongs to both the high number and heterogeneity of organizational units (radiology units, hospital wards, laboratories, administration), professionals (radiologists, radiological technician, medical and administrative staff, nurses), and final users (clinicians requesting examinations and outpatients) involved in the system workflow. This is the reason why PACS are also defined "diffuse technologies".[6]

Studies often lack in holistic approach,[7] and a few are those aiming to forego an overall assessment of these systems in terms of technological architecture, economic impacts, changes in the organizational processes, individual productivity, diagnostic effectiveness, and user satisfaction[8,9]. Two good examples are the evaluation project carried out at the Trieste hospital[10] and at the Baltimore Veteran Affairs Medical Centre[11]. However, the specific characteristics of the systems in use does not allow generalizations, as a PACS may be implemented with different levels of integration with the Radiology Information System (RIS) and with the rest of the Hospital Information System (HIS), and many are the evaluation variables analyzed in the literature.

The literature elaborates on the issue of evaluating the implementation of PACS from different perspectives and—as already mentioned—with a wide range of results. However, the different approaches adopted can be grouped into four categories according to the variables analyzed in the studies:[10,12]

1. the *economic approach*, aimed at assessing the economic and financial impact mainly by means of cost-benefit analysis;
2. the *organizational approach*, oriented to assess the impact of the innovation on productivity at the individual (e.g., time saved for managing the different stages of the production process) and organizational level (e.g., variation in the number of examination);
3. the *clinical approach*, focused on the perceived impact that PACS has on users, with respect to ease of interfacing with the new system, and on the patient (clinical effectiveness), the final beneficiary of the output produced by the technology;
4. the *technological approach*, aimed at assessing the system's performance (e.g., picture quality, transfer speed, archiving capacity) and the requisites of integration with respect to other information systems (e.g., diagnostic equipment, the RIS, the hospital Intranet) and existing standards.

Table 1 classifies existing literature with respect to the first three approaches, on which the study focuses.

Several interesting dimensions of analysis emerge from the literature review. In the next section, we investigate each dimension substantiated by the literature and formalize some hypotheses which will be tested on the basis of the survey results.

Main Evaluation Dimensions

The literature on PACSs evaluation makes the first important distinction between:

- Those systems which can be exploited by all the hospital's departments *(large in-scale*, or *wide-area*, or *whole hospital* PACS);
- Those systems whose functionalities are limited to the radiology department (*small in-scale* or *department only* PACS).

Large In-Scale PACS is fully integrated with the Hospital Information System (HIS), so that it can be exploited by all of the hospital's departments, thus resulting in the full digitalization of the entire production process—picturing, archiving, and distribution—of diagnostic images that are filmless provided to the requesting users (hospital wards and outpatient clinics). Even the request process is usually fully paperless.

There are already several case studies highlighting the main features of this type of systems: the cases of SMZO Hospital in Vienna[69] and Hammersmith Hospital in London,[30] the Baltimore VA Medical

Table 1. Main Literature Classified by Assessment Approach

Assessment approach	References
Economic approach	2,8,13–31
Organizational approach	Individual productivity analysis 2,5,12,24,29,31–54
	Hospital productivity analysis 2,7,18,24,29,50,55
Clinical approach	User perception analysis 2,9,12,29,54,56–61
	Patient impact analysis 2,12,18,24,29,36,44,52,60,62–68

Hospital,[2,29] the aforementioned implementation at Trieste Hospital,[10] the Taipei City Hospital Heping Branch,[13] a large public hospital in Melbourne,[7] Hospitals Leuven, Belgium,[70] the Toolo Hospital, Helsinki University Central Hospital, Finland[41].

Small In-Scale PACS can be employed exclusively in the radiology department, or it may be extended to those hospital wards most closely linked to the radiology department (e.g., intensive care units). The exams' request process from the hospital department is usually paper-based and also the diagnostic images are usually delivered to departments or patients on films.

The literature generally emphasizes that the degree of scale of PACS may contribute to improve the diagnostic process, in terms both of efficiency and clinical effectiveness.[51,71,72] Therefore, we expect to observe higher impacts on productivity measures for whole in-scale PACS.

HP 1: Whole in-scale PACS have a higher impact on productivity and effectiveness compared to small in-scale PACS.

Another important characteristic is the degree of PACS integration with: (a) the radiology department's diagnostic modalities, (b) RIS, (c) HIS (For whole in scale PACS, the minimum degree of integration guaranteed between the PACS and the HIS consists of the electronic request form and inline display for the other wards and outpatients clinics in the hospital, whereas the full integration of clinical images with electronic medical records is an additional feature, which may or may not be offered by the whole PACS), or (d) other healthcare organizations' technologies (*network* PACS[73,74]). In particular, the first aspect is an indicator of the degree of digitalization of the radiology department; consequently, it may enhance PACS efficiency in some stages of the diagnostic process.[7] Furthermore, the integration between RIS and PACS allows the radiology department to enhance efficiency and effectiveness.[75]

Finally, many authors show that only full integration between the RIS, PACS, and HIS foster the extension of the benefits to the whole organization, including positive impact on the quality of services provided to inpatients and outpatients.[12,37,43,65,70,76] Full integration enables the complete digitalization of the X-ray ordering stage and the image and report transfer/display stage (by means of PACS workstations located on the ward or with direct PACS connection), thus allowing the recording of images and reports in the patient's electronic medical records (For whole in scale PACS, the minimum degree of integration guaranteed between the PACS and the HIS consists of the electronic request form and inline display for the other wards and outpatients clinics in the hospital, whereas the full integration of clinical images with electronic medical records is an additional feature, which may or may not be offered by the whole PACS). In particular, the literature emphasizes the importance of the level of integration with the patient's electronic medical records to extend the PACSs' benefits to the clinical process.[2,70,72,77,78]

HP 2: The PACS integration with the radiology department's diagnostic modalities, RIS/HIS and the electronic medical record (EMR) leverages the overall PACS benefits.

These first two hypotheses refers to specific implementation strategies (i.e., extension and integration), rather than characteristics of the adopted PACS technology. We test these two hypotheses within those of the further six hypotheses which, according to the literature, may be influenced by the implementation strategy. In other words, we verify whether an extension strategy and/or integration strategy impacts on the PACS performances tested through the other hypotheses referring to PACS' features (HP3–7).

The cost-benefits analyses conducted in the empirical studies mainly focus on the variation of three resources (in addition to the initial investment cost): personnel, consumables, and space dedicated to the archives.

As far as personnel is concerned, studies assessing the impact associated with organizational processes redesign find out, on one hand, stability in the number of clinical and technical personnel and, on the other hand, a drop in the number of administrative personnel (secretarial tasks and filing).[2,11,13,79] However, this effect does not depend exclusively on the technology. Rather, it is the result of the analysis and redesign of the organization processes coherent with the PACS scale,[13] the new technology potentialities,[40,80] and the skills of the people involved in the change.[26,70,81]

HP 3: PACS does not impact significantly the number of clinical and technical personnel,

but it tends to reduce the administrative one; however, the impact is strictly related to the organizational process redesign occurred after the introduction of the innovation.

As far as space and consumables are concerned, literature emphasizes reduction of the consumables used (e.g., reduction of film cost) and savings in terms of archiving space.[13,31,82]

HP 4: PACS reduces the use of consumables and the space dedicated to radiological archive.

Productivity of radiological workflow is another variable that several studies analyze in specific hospital contexts,[36,53] showing efficiency enhancements in managing tasks of the radiological process. For instance, some studies measure the time spent in each phase of the diagnostic process with PACS compared to other hospital using traditional systems.[32,67] In particular, the literature assesses four specific phases of the diagnostic process:

- Execution of the examination (including image capturing), where productivity is most affected by the upgrade of the technology equipment[35,46,47,83] and by the level of integration with RIS and HIS[37,43];
- Report generation (report turnaround time), although there is no unique evidence[38] about what speeds up the time of report production[41]. In particular, some factors which can contribute to PACS impacts are: certain technical features of the diagnostics workstations—which may lead to longer time for the formulation of the diagnosis[36,84]—the radiologist's familiarity with the equipment,[46] and the technological integration of specific activities previously handled by administrative staff (e.g., speech recognition system instead of report dictation and transcription[85] and electronic signature system[86]);
- Recovering images from the archives, with a productivity improvement thanks to the PACS digital archiving system[79,87];
- Images delivery, where productivity increases if PACS is extended to other departments or hospitals[88–90] or external ambulatories.

Other studies focus on the impact on the number of examinations managed periodically. They generally find out an overall workload increase.[7,11,18,55]

HP 5: PACS enhances the productivity of the radiological process both in terms of time spent in specific phases of the process and number of examinations managed.

Holding the aforementioned productivity impacts, it is important to consider that the literature agrees on the fact that a PACS does not generate such cost savings as to fully justify the investment under the financial perspective. Consequently, it is necessary to extend the analysis towards "indirect" benefits linked to the system's capacity of offering patients more appropriate and effective services (so called *intangibles*). However, evidence supporting PACS impact on the overall health care delivery process quality is still lacking.

Generally, clinical effectiveness has been identified in literature[17,62] with respect to: the risk of error while carrying out examinations (resulting in the need to repeat the examination and thus subjecting the patient to greater doses of radiation),[11,52] the difficulty in interpreting the image (which is no longer developed on film but is examined on screen), the risk of image interpretation error while producing the medical report, the rapidity for the formulation of a clinical diagnosis,[36,44,65] the accuracy of image interpretation,[67] the waiting list length (literature does not show evidences, but presents only estimates and forecasts), the average length of stay in the hospital, the number of lost examinations[66].

As far as the waiting lists are concerned, the literature interprets the impact of PACS as the result of two conflicting phenomena. On one hand, PACSs allow for efficiency improvements in the diagnostic processes, speeding up all its phases and reducing the time needed to obtain radiological results and, consequently, the waiting lists.[75] On the other hand, the aforementioned enhancements improve patients' confidence, thus stimulating the demand for these services and contributing to the increase in the waiting lists.[91,92]

HP 6: PACS positively impact clinical effectiveness in terms of reducing the risk of errors during the diagnostic process.

Another evaluation perspective analyzed in literature is the perceived usefulness of the system with regard to specific categories of users, in particular radiologists and technicians.[9,12,58]

HP 7: PACS are generally perceived as useful by radiologists and technicians.

Finally, the implementation of PACS seems to be more cost-effective for hospitals with medium–large radiology units (both in terms of the number of personnel and workload). The statement belongs to the assumption that the larger the organizational unit, the higher the complexity of radiology processes because of the number of staff and the volume of activities. This leads us to presume that the average size of the radiology unit can contribute to explain the hospital decision of adopting PACS technology.

HP 8: *The radiology department activities volume is a driver for the decision for PACS adoption.*

In the next section, we describe the data collection method and the sample. Then we test all the aforementioned hypotheses on the basis of the Chiefs Radiology Department's experience and perceptions. Although the study represents a case of summative evaluation (i.e., intended to answer questions about whether or not certain effects are associated with the introduction of PACS), we try to test the relevance of certain explaining factors mentioned in the literature. However, any process analysis aiming to define pattern of causation—although very interesting—is out of the scope of this study.

MATERIALS AND METHODS

The survey regarded the public healthcare organizations offering hospital type services: autonomous hospitals (the autonomous hospitals in the Italian NHS are similar to the British NHS Trusts) and hospital directly managed by Local Health Units (LHU (LHUs are responsible for the health of the Italian population resident in a given area—about 300,000 on average. They accomplish their duty by providing health services or—for those not managing hospitals—buying health services from autonomous hospitals on behalf of their citizens.). The list of structures is the one reported in the Department of Health's 2005 Yearbook and includes 531 hospitals. The survey was conducted from the beginning of July to mid-September 2006, by means of a telephone questionnaire answered by the senior radiologist in charge of the radiology department management (i.e., chief radiology department). Members of the research team first tested the questionnaire on a subsample of senior radiologists, to assess its clarity and accuracy. The interviewers were trained in a briefing where the objectives and rationale of the study were presented along with the questionnaire. The questions (mainly multiple choice ones) aimed at gathering information concerning three aspects: characteristics of PACSs already implemented, impacts produced by such system with respect to hospital efficiency (in terms of changes in availability of resources—*input*—and on the diagnostic processes—*output*) and effectiveness of the services provided to patients (clinical dimension linked to the quality and accuracy of services—*outcome*) and the future developments concerning PACS.

The data were collected using computer-assisted telephone interviewing (CATI) technology on a sample of healthcare organizations: the survey was conducted on the whole population, but the participation in the study was voluntary.

The response rate equals 49.7%, and Tables 2 and 3 show that the sample is representative with respect both to the geographical area and the type of structures. The proportions of respondents are aligned both with the geographical distribution of facilities in the country (percentage of population per area) and with the number of the two types of hospitals (autonomous ones and hospitals directly managed by LHU) in the National Health Service. The sample composition shows a slight overrepresentation of the north and an underrepresentation of the center.

Table 2. Sample Composition (Geographical Breakdown)

	Population		Respondents		Response
Area	Frequency	Percent	Frequency	Percent	rate
North west	74	13.9	38	14.4	51.4
North east	80	15.1	49	18.6	61.3
Center	129	24.3	53	20.1	41.1
South and Islands	248	46.7	124	47.0	50.0
Total	531	100.0	264	100.0	49.7

Table 3. Sample Composition (by Type of Hospital)

Type of Hospital	Population		Respondents		Response rate
	Frequency	Percent	Frequency	Percent	
Hospital	98	18.5	45	17.0	45.9
Hospital directly managed by LHU	433	81.5	219	83.0	50.6
Total	531	100	264	100	49.7

RESULTS

Diffusion of PACSs in the Italian NHS and Their Main Features

According to the survey (see Table 4), 91 Italian hospitals (i.e., 34.4% of the sample) employ a digital system for capturing and managing clinical images.

PACS Scale

Almost half of the hospitals with a PACS had a small in-scale solution (i.e., radiology department only PACS), while an equal number had opted to extend the new system to other hospital departments and wards (i.e., whole in-scale PACS; Table 5).

The structures located in the southern Italy and the islands have lower PACS installation rates (18.5%) compared to the national average and a prevalence of small in-scale solutions (65.2%). The situation differs in the other geographical areas, where almost half the sample hospitals use a PACS, and a significant number of these opted for whole scale systems (see Table 6).

Integration with Diagnostic Modalities

In 80% of cases, the PACS links all the diagnostic modalities used in the radiology department (Table 7). This configuration is adopted more commonly by hospitals that employ a whole in-scale PACS (91%), whereas it is relatively less common (69%) in structures opting for a small in-scale PACS.

Table 4. PACS Ownership in the National Health Service

Parameter	With PACS	Without PACS	Total
Sample proportion	34.4%	65.6%	100
Number of hospitals	91	173	264

Table 5. PACS Scale

Parameter	Small In-Scale PACS	Whole In-Scale PACS	Total
Proportion of the sample	17.0	17.4	34.4
Number of cases	45	46	91

Integration with RIS

Almost all the sample hospitals (92%) show PACS integrated with the RIS. Consequently, their information system enable image management integrated with the medical report production and the electronic management of the unit's work lists.[93]

This data is confirmed by the fact that 74% of the hospitals using PACS have the same supplier for both RIS and PACS. This should safeguard full system compatibility and integration.

Integration with Electronic Medical Records

The survey outlines a limited number of installation of electronic medical record systems (EMR) in the hospitals adopting PACS (27.8%). However, only 17.6% of hospitals adopting PACS declare integration between the PACS and EMR, with a higher rate among whole in-scale PACS (22%).

The potential offered by such integration does not appear to be fully exploited yet, not even by hospitals with whole in-scale PACS. Indeed, the working practice of the wards still requires radiological reports to be signed by hand in 79% of cases, thus not allowing a paperless management of the clinical reports.

PACS Implementations: Recent Trend

With respect to the implementation period, over half of the PACS were introduced during the last

Table 6. PACS Installation by Geographical Area

Parameter	North West (%)	North East (%)	Centre (%)	South–Islands (%)
Hospitals with PACS	50.0	49.0	47.2	18.5
Small in-scale PACS	42.1	45.8	44.0	65.2
Whole in-scale PACS	57.9	54.2	56.0	34.8

Table 7. Level of PACS Integration

PACS integrated with	Hospitals with PACS (%)	Small In-Scale PACS (%)	Whole In-Scale PACS (%)
Diagnostic modalities	80.2	69.0	91.0
RIS	92.3	91.1	93.5
Electronic medical record (EMR)	17.6	13.0	21.7

3 years (2004–2006), with a higher rate (61%) for whole in-scale PACS. This confirms the recent growing trend of adoption of this technology in Italy.

Hypotheses Testing

The survey analyses the evaluation dimensions emerging from the reviewed literature. In particular, the questionnaire focuses on the changes related to PACS and affecting the following elements:

personnel in the radiology department (HP3);
consumables and space (HP4);
productivity of the radiology department, in terms of both time spent in specific phases of the process and number of examinations managed (HP5),
clinical effectiveness (HP6)
PACS perceived usefulness (HP7)

Furthermore, within each of the aforementioned hypotheses, we test the additional/leveraging benefit related to the PACS extension (HP1) and integration (HP2) strategies adopted in the PACS implementation. Finally, the questionnaire explores whether the radiology department size (in terms of volume of activities) influences the decision of PACS adoption (HP8).

Personnel in the Radiology Department

Results seems to confirm HP3, as the number of administrative personnel decreased in 32.2% of the cases, while 64.5% of the interviewed declares no change. In 55% of the cases, the Chief Radiology Department claims a reduction of personnel in charge of the archives (Archiving deserves a specific comment: physical archive is expected to be gradually phased out with the introduction of full process digitalization. However, the existence of a paper-format archive (almost never scanned) and the often partial digital integration of radiology (with the result of maintaining the medical reports in a paper format), limit the potential benefits in terms of reduction of personnel involved in the process.). On the contrary, radiologist and technical personnel decrease only in 7.7 and 8.9% of cases, respectively.

Table 8. Impact of PACS on Hospital Human Resources

Parameter	Increase (%)	Reduction (%)	No change (%)	Total (%)
Personnel				
Radiologist clinician	2.2	5.5	92.3	100.0
Radiologist technicians	4.4	4.4	91.2	100.0
Administrative personnel	3.3	32.2	64.5	100.0
Archive personnel	2.2	54.9	42.9	100.0

Table 9. Impact of PACS on Consumables and Space

Parameter	Increase (%)	Reduction (%)	No change (%)	Total (%)
Consumables	3.3	91.2	5.5	100.0
Space	0.0	82.4	17.6	100.0

The percentage of hospitals recording a rise in personnel are less than 5% with regard to all professional roles (Table 8), perhaps due to scarce redesign effort. Indeed, the great majority of hospitals (83.5%) redesigned their radiology department processes after the introduction of the PACS. This may lead to the conclusion that positive impacts on personnel is strictly related to the change management, thus supporting also the second part of HP3.

In this case, HP1 is not supported, as no statistically significant difference (Mann–Whitney Test, $p>0.05$) resulted when comparing small in-scale with whole in-scale PACS cases. HP2 is not supported either. Therefore, the implementation option does not seem to influence the impact on personnel. Thus, we might conclude that the digitalization itself (i.e., elimination of physical items and the burden related to their handling) is the relevant factor explaining PACS impact on personnel.

Consumable and Space for the Radiology Department

More than 90% of hospitals with PACS claim a reduction in consumables cost, thus confirming HP4 (Table 9). In addition, a significant recovery of space dedicated to archives is confirmed in 82.4% of the cases. No statistically significant difference (Mann–Whitney test, $p>0.05$) was found when

Table 10. PACS Impact on Individual Productivity

Parameter	Reduction (%)	Increase (%)	No change (%)	Do not know (%)	Total (%)
Time for execution of examination	42.9	6.6	49.4	1.1	100.0
Time for producing medical report	47.2	25.3	27.5	0.0	100.0
Time for recovery of images from archive	90.1	2.2	7.7	0.0	100.0
Time for distribution of image/medical report	70.8	0.0	28.1	1.1	100.0

comparing whole in-scale PACS cases with small in-scale ones, thus not supporting HP1. In addition, implementation strategies based on PACS integration with EMR and/or diagnostic modalities do not seem to enhance this kind of benefit (Mann–Whitney test, $p>0.1$), thus not supporting HP2 either. This result is aligned with the previous analysis of the impact on personnel, thus confirming the relevance of digitalization itself.

Workflow Productivity

As PACS impacts differ according to the phase of the diagnostic process, we focused the attention on four of the stages most analyzed in literature: recovering images from the archives, images distribution, execution of the examination (including image capturing), and medical report issuing.

With regard to the time spent in the execution of examinations, no significant change was claimed in almost half of the cases, while 43% of organizations report a reduction compared to when employing traditional technology. However, 44% of the hospitals with PACS intend to buy new image acquisition technology in the short term. This could lead to a gradual reduction in the time spent in this phase, as some authors[34,47] found a significant reduction in the acquisition time when diagnostic modalities were used to directly produce images in digital format.

In 47.2% of cases, the time for the medical report generation was noted to be shorter, while 25.3% increased after the introduction of the PACS. This variation confirm the one in literature,[38,41] and it mainly belongs to PACS integration with the voice reporting systems/software (82.4%); it allows radiologist to produce their own medical reports without the help of typists and/or secretarial staff employed to type them up.

The activities aimed at recovering images from the archives resulted in the ones where the time frame is most frequently shortened (92% of the cases and in all the hospitals whose PACS is extended to the wards), followed by the activities related to the distribution of images and medical reports to the ordering departments (71% of the cases). In particular, the shortening of the time frame relating to image distribution is statistically related to the implementation of whole in-scale PACS (Mann–Whitney Test, $p<0.01$) and to the integration with the radiology department's diagnostic modalities (Mann–Whitney test, $p<0.1$), thus supporting also HP1 and HP2, limited to diagnostic modalities. Hence, whenever the radiology department deal with information exchanges with other organization units, the implementation strategy ranks high as explaining factor of the outcome reported (as opposed to the impacts on personnel, space, and consumable).

Table 10 shows a reduction of the time necessary for image/report distribution (almost 71% of the cases). One more time, the fact can be explained in terms of enhanced efficiency of distributing digital data rather than physical items.

The data relating to time variation in each phase explains the impact in terms of personnel working in the radiology department; substantially stable number of medical and technical staff, drop in the number of administrative staff. With the exception of the second phase, the results seems to support the first part of HP5.

With regard to the volume of outputs produced by the radiology department, the number of examinations increased in half of the cases after the introduction of the PACS. However, no significant

Table 11. Cases of Increased Individual Productivity (Compared to the Volume of Activity)

Parameter	Hospitals with PACS (%)	Hospitals with Small In-Scale PACS ((%))	Hospitals with Whole In-Scale PACS (%)
Radiologists	51.6	55.6	47.8
Technologists	52.2	53.3	51.1
Administrative staff	65.6	63.6	67.4
Archive staff	75.8	75.6	76.1

Table 12. Average Work Volumes and Number of Staff in the Ward

Parameter	With PACS	Without PACS
Radiology department size indicators		
Volume of examinations[a]	100,195.82	62,968.37
Number of patients[a]	67,567.57	40,821.58

[a]Statistically significant at 99% confidence level

change is declared in 48% of the cases which adopted the technology.

This data was cross-referenced with the information regarding changes in personnel to test individual productivity. In particular, we consider increased hospital productivity either the reduction of personnel associated with an increase/stability in the number of examinations or the increase of output volume associated with a stable personnel. We check this aspect for all the professional roles: medical, technical, and administrative (Table 11).

For medical personnel, greater productivity was recorded by 51.6% of hospitals which introduced PACS. Considering the high rate of stability in the staffing structure, this efficiency can be ascribed to the greater workload (Table 12) that individual professionals are able to handle thanks to the new system (89.3% of the efficiency enhancement can be explained by the increased volume of examinations done by the same personnel). Productivity was found higher for small in-scale PACS (55.6%).

With regard to technical personnel, productivity improvement was reported in 52.5% of the cases (91.5% of the enhancement motivated by increased volume of examinations done by the same number of people), with a slightly higher percentage for small in-scale PACS.

For administrative staff, an increase in productivity was reported by 65.6% of hospitals which introduced PACS, with whole in-scale PACS hospitals reporting slightly higher rates than average (67.4%). Focusing the attention on the sole personnel in charge of archiving tasks, a productivity gain emerges in almost 76% of the cases. This last outcome can be easily ascribed to the elimination of physical items too, as it is supposed to reduce the burden of classifying, storing, and retrieving documents. Consequently, at least in terms of perceptions, results seem to support also the second part of HP5.

Clinical Effectiveness

The survey shows a perceived reduction of both the risk of mistakes during the execution of the examination (82.4% of cases) and risk of interpreting erroneously the images (63.7% of cases; Table 13).

Much more uncertain is the impact of the new system on the average stay in the hospital: about 21% interviewees were not able to estimate the impact, while almost 41% reported an increase. Considering the uncertainty expressed by a significant part of the interviewees, we are not comfortable in drawing conclusions about this aspect.

Finally, 71% of the hospitals reported a drop in the number of lost examinations. According to expectations, perceptions are even better in those hospitals where the images are electronically distributed to the ordering units: 85% for whole in-scale PACS.

Therefore, results support the HP6, although they do not help to clarify the impact on the length of stay. This is not in contrast with the literature, but does not add any elements to enhance our knowledge about these aspects. However, the diffuse claim of a drop in lost examination may suggest a direction to further research.

Overall Perceived Utility of the System

With respect to the perception of the PACS utility, 97.8% of the sample declare an increase of

Table 13. PACS Impact on Clinical Effectiveness

Parameter	Reduction (%)	Increase (%)	No change (%)	Do Not Know (%)	Total (%)
Risk of error in the execution of examinations	82.4	0.0	17.6	0.0	100.0
Image interpretation difficulties	63.7	9.9	26.4	0.0	100.0
Risk of diagnosis error	48.3%	6.6%	41.8%	3.3	100.0
Waiting lists	9.9	16.5	71.4	2.2	100.0
Average stay in hospital	0.0	40.7	38.4	20.9	100.0
Number of lost examinations	79.1	0.0	17.6	3.3	100.0

Table 14. Strategies for the Future

Parameter	Without PACS (%)	With PACS (%)		
			Small In-Scale	Whole In-Scale
Purchase new and updated diagnostic modalities	37.6	44.0	40.0	47.8
Purchase PACS	69.4	–	–	–
Purchase RIS	40.5	–	–	–
Purchase a new PACS	–	6.6	4.4	8.7
Purchase a new RIS	–	7.7	6.7	8.7
Expand the existing PACS to other wards	–	60.4	82.2	39.1
Adhere to multi-hospital PACS projects	24.9	44.0	42.2	45.7

the perceived quality of the radiology services provided, thanks to the PACS. This statement confirm HP7, and it is consistent with the future strategies regarding the development of the system (see next subsection).

Influence of Volume of Activities on the Adoption Decision

To verify whether the size of the radiology department is associated with the existence of a PACS, the survey collected information about the volume of the activities carried out by the radiology unit. In particular, we asked the number of radiology examinations performed in 1 year and the number of the radiology unit's patients per year.

Results show that on average, hospitals adopting PACS have a radiology department size larger compared to hospitals without PACS (Table 12). This seems to support HP8, although identifying the explanatory factors of this outcome requires further analysis, and it would be useful to support such an important aspect.

Table 15. Degree of Support of Initial Hypotheses

HP number	HP Description	Degree of Support	Notes
HP1	Whole in-scale PACS have a higher impact on productivity and effectiveness compared to small in-scale PACS	Partial	Shortening of the time frame related to image distribution
HP2	The PACS integration with the radiology department's diagnostic modalities, RIS/HIS and EMR leverages the overall PACS benefits	PARTIAL	Shortening of the time frame related to image distribution limited to diagnostic modalities integration
HP3	PACS does not impact significantly the number of clinical and technical personnel, but it tends to reduce the administrative one;	Full	
	however, the impact is strictly related to the organizational process redesign following the introduction of the innovation	Full	
HP4	PACS reduces the use of consumables and the space dedicated to radiological archive	Full	
HP5	PACS enhances the productivity of the radiological process: both in terms of time spent in specific phases of the process and	Partial	Time reduction confirmed
	Number of examinations managed	Partial	Increased number of examinations confirmed only in perceptions
HP6	PACS positively impact in clinical effectiveness in terms of reducing the risk of errors during the diagnostic process	Full	Impact on length of stay unclear
HP7	PACS are generally perceived as useful by radiologists and technicians	FULL	
HP8	The radiology department activities volume is a driver for the decision for PACS adoption	Full	

Future Scenario

The developments which may concern PACS have been classified with respect to the following strategies (Table 14): (a) acquire new diagnostic technology for image acquisition (modalities); (b) acquire/replace the PACS; (c) acquire/replace the RIS; (d) adhere to interhospital (networked) PACS projects. The aforementioned strategies are the guidelines towards a scenario of full digitalization of the diagnostic process.

According to the hospitals already employing PACS, the priorities are: expanding the system to other wards (about 60% of the cases) mainly for hospitals with a small in-scale PACS (67%). Two other priorities (in 44% of cases) are adhesion to interhospital projects and purchasing new and updated diagnostic modalities. Only few interviewees stated the intention to replace the current PACS (7%) and RIS (8%).

Among hospitals which had no PACS in place, about 69% stated the want to purchase one in the short term; about 40% intended to replace/acquire RIS and almost 38% intended to introduce new or more updated diagnostic modalities. Almost 25% intends adhering to multihospital PACS projects

DISCUSSION AND CONCLUSIONS

Table 15 summarizes the degree of support provided by our research to the initial hypotheses. Four hypotheses on seven are fully confirmed, one is partially confirmed and one is unconfirmed.

As far as HP3 is concerned, on the one hand, PACS technology in Italian hospitals clearly enables hospitals to focus on core clinical operations, making technical–administrative duties less costly in terms of the resources absorbed for their management. On the other hand, the lack of significant reductions of the number of clinical and technical personnel may be determined by the widespread rigidity in the organizational set up of public hospitals,[94] thus fostering a perception of status quo. Given the limited tendency to dismiss public sector employees, renewed efficiency in a given area may represent an opportunity for the hospital to employ any "excesses" for upgrading other weaker areas within the hospital itself: in this case, the cost "saved" at ward level represents an opportunity for the hospital to strengthen areas in the process which were managed in "emergency" mode before.

As far as PACS implementation methodology is concerned, the results confirm the same conclusions related to the potential benefits of other IT infrastructures (e.g., document management systems) in healthcare organizations.[26] Specifically, this kind of technology is characterized by:

- Need for large initial investment;
- Requirement of adaptation time for acquaintance with the new procedures;
- Identification of new channels of communication for the output (digital) and integration opportunities with other technological solutions (e.g., RIS, EMR, etc.) to transfer the potential benefits downstream, towards patients.

Finally, the authors are aware of the major limits of their study. First, the survey has so far involved only the Radiology Unit, thus not allowing the assessment of PACS at a hospital level. Second, the study does not deal with the impacts belonging to multihospital PACS sharing; a first and rough view of the future strategies of multihospital PACS projects in Italy is provided in Table 14, suggesting this strategy as a relevant future trend. These are some of the main interesting directions for further research.

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