

Evaluating the Implementation of Picture Archiving and Communication Systems in Newfoundland and Labrador—a Cost Benefit Analysis

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INTRODUCTION

Picture archiving and communication systems (PACS) present an opportunity to radically change film-based radiology services both inside and outside the hospital setting. In the past, the usual medium for capturing, storing, retrieving, and viewing radiology images was hard copy film. The idea to replace film with digital images was first conceptualized in 1979.¹ However, it was not until the early 1980s that advances in technology made introducing PACS into radiology departments feasible.² PACS replaces the film environment with an electronic means to communicate and share radiology images and associated reports in a seamless manner between health professionals.

During the period 1998–2002, the province of Newfoundland and Labrador (Canada) implemented PACS on a project basis across its eight regional health authorities. Following a reduction in health authorities from eight to four in 2003, implementations of PACS continued such that by early 2005, approximately 70% of Newfoundland and Labrador service delivery areas had PACS capability. However, with this expansion came increasing concerns with the quality and capacity of image storage, the long-term sustainability of these systems, and their disaster recovery capabilities. As well, many of these PACS sites had yet to achieve a 95% filmless state, which resulted in

achieving less than maximum savings (e.g., elimination of film costs), and that because of these reduced savings, most sites were not able to offset the initial or ongoing maintenance costs of these earlier PACS.

In the fall of 2005, Canada Health Infoway (Federal Government) and the Newfoundland and Labrador government (Provincial Government) partnered on a \$23 million initiative to implement one of the first *province-wide* PACS in Canada. This initiative had two overall objectives: (1) to implement PACS in selected rural sites where no PACS currently existed and (2) to address gaps in those regions where PACS was currently operational. The provincial vision for PACS was one that would provide access to any patient, any image, any report, anywhere, and anytime. In realizing this vision, referring physicians and radiologists could view their patient's images and/or reports in a hospital, their office, or even in their homes.

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In November 2007, the province of Newfoundland and Labrador completed implementation of its provincial PACS, one of the first of its kind in Canada. A benefits evaluation was undertaken to determine the impact that PACS implementation had within the province. As part of the larger evaluation, a cost benefit analysis was carried out in the Western Health Authority, a region that encompassed eight acute care sites where PACS was to be implemented.

When considering the financial impact of PACS, benefits can basically fall into two categories: cost savings and increased revenues/profit. Cost savings (sometimes referred to as cost avoidance) are achieved through the elimination of costs associated with activities such as reducing staff levels needed for maintaining the hard copy film library,^{3,4} eliminating cost for chemicals and film,^{3,4} eliminating transportation costs,^{3,5-7} and freeing up space historically used to house hard copy film.³⁻¹⁰

Where sites are paid for each radiology service provided to a patient, PACS can provide an opportunity to increase revenues. This is made possible when radiologists become more efficient in reviewing digital exams (images) and preparing reports for referring physicians. With this increased efficiency, hospitals can accommodate more new patients (i.e., increase productivity) from their pool of referring physicians.¹¹⁻¹⁵ In Canada, delivery of health services is financed through the Canada Health Transfer (CST), which provides universal health care insurance to all residents of Canada. The CST is conditional and must be spent on health. Legislation such as the Canada Health Act specifies standards that the provinces must maintain in order to receive CST funding. Therefore, PACS provides limited opportunity for hospitals in Canada to generate revenues by increasing the number of patients seeking radiology services. Nevertheless, from an accountability perspective, investments in health information systems are costly and it is necessary to quantify the success of such systems and the degree to which the investment was justified.¹⁶ Challenges to addressing these concerns include (1) efficiency (doing things right) is easier to measure than effectiveness (doing the right thing), (2) new systems are intended to change difficult to measure actions, (3) strategic systems elude measurement, and (4) infrastructure investments

cannot be justified on a return on investment (ROI) basis. Adding to the challenge is that the literature is not conclusive on whether PACS can actually result in savings and/or increase revenues/profits^{5-10,13,17,18} given that the level of benefit achievement depends on a multitude of confounding factors, such as the funding model in place, the size and type of the PACS site and the population served,¹⁹ and how efficient the film site was before PACS was implemented.²⁰

MATERIALS AND METHODS

The setting for the study was the Western Health Authority which is located on the west coast of Newfoundland and Labrador, the eastern most province in Canada. The province has a population of approximately 505,000 (2007) and is separated into four health authorities. The Western Health Authority serves a population of approximately 80,000, or 16% of the total provincial population (Table 1).

The Western Health Authority has eight PACS sites, two of which are considered acute care hospitals, of which one (hospital A) serves as the main acute site for the region; the remaining six sites are considered health centres. Modalities in scope for the cost per case analysis included CAT scan, echocardiography, magnetic resonance imaging (MRI), nuclear medicine, general radiograph, and ultrasound. The number of acute care beds and exam volume for each of the eight sites across the six modalities in scope as of December 2006 is presented in Table 2.

Annual expense details for costs associated with radiology exams were collected for 12 months pre and for 12 months post-PACS implementation.

Table 1. Population (2006) by Health Authority Newfoundland and Labrador

Health Authority	Population
Eastern	293,682 (58.1%)
Central	95,607 (18.9%)
Western	79,034 (15.6%)
Labrador-Grenfell	37,146 (7.3%)
Province	505,469 (100.0%)

Source: NL Centre for Health Information/Statistics Canada

Table 2. Exam Total by Number of Acute Beds by Site (2006)
Western Health Authority

Site	Modality	Acute beds	Total exams
	CAT scan		9,831
	Echocardiography		1,689
	MRI		6,472
	Nuclear medicine		3,646
	General radiograph		46,041
	Ultrasound	186	9,977
Hospital_A	Total exams		77,656
	General radiograph		13,846
	Ultrasound	40	2,881
Hospital_B	Total exams		16,727
	General radiograph		5,864
	Ultrasound	20	1,452
Hospital_D	Total exams		7,316
	General radiograph	13	5,963
Hospital_G	Total exams		5,963
	General radiograph	1	1,134
Hospital_F	Total exams		1,134
	General radiograph	6	1,667
Hospital_E	Total exams		1,667
	General radiograph (Day clinic only)		2,204
Hospital_C	Total exams		2,204
Total exams within scope for all sites			112,667

Sources of data used in the collection process included Canada Health Infoway’s reimbursement schedules, financial and budget spreadsheets provided by the Western Health Authority, and project budget documents provided by the Newfoundland and Labrador Centre for Health Information (NLCHI). The NLCHI was established in October 1997 with a mandate to improve the health and well-being of the people of Newfoundland and Labrador by making quality health information available to the public, health professionals, government, regional health authorities, and other organizations and agencies. NLCHI also has the responsibility for the implementation and project management of a province-wide Health Information Network (HIN) and specific domains of an Electronic Health Record (EHR). The main operational cost for which financial data was collected for both the film and PACS environments is provided in Table 3. The financial analysis examined a 5-year window as described below in Table 4.

RESULTS

Figure 1 presents the total number of exams produced for the Western Health Authority for years 2003/2004–2007/2008. In 2004/2005, there was a change in the province for reporting radiology exams under the Management Information System (MIS) Guidelines. Prior to 2004/2005, if a patient had one procedure (e.g., dye injection) and one positioning but had two exams taken (e.g., hip and back), the number of exams reported was two, one each for the hip and back. In 2004/2005, this was changed such that, using the above example, only one exam would be reported under the new MIS Guidelines.

The final costs for PACS hardware, software, human resources, and data storage in the Western Health Authority are provided in Table 5. Networking costs for PACS are excluded, given that the provincial network infrastructure is being employed by the province to support all EHR traffic, not only PACS. Further, all networking costs associated with the provincial HIN will be the responsibility of the Ministry of Health, not the regional authorities. Costs for EHR network

Table 3. Budget Items for Which Data Collected Western Health Authority

Exam utilization
Total exam volume
Estimated exam volume increase
Film environment
Film
Master and insert bags
Paper-related expenses
Chemical purchase
Chemical disposal
Maintenance
Courier
Storage
Staff
Librarians/clerks
Dark room staff
PACS environment
Site-specific PACS services
Local image volume maintenance
Network service contract
PACS service contract
Data center support maintenance
Staff
PACS administrator
PACS support staff

Table 4. Transition from Film to PACS for Modalities in Scope Western Health Authority

Year	Environment	Comment
2003/2004	Film	No PACS
2004/2005	Film	No PACS (base year for film)
2005/2006	Film/PACS	PACS sites went live Dec 2005–Jun 2006
2006/2007	PACS	98% filmless (modalities in scope)
2007/2008	PACS	100% filmless (modalities in scope)

infrastructure in any jurisdiction is highly variable and will depend on many factors, including the number of sites involved, the amount of traffic on the network, and the desired speed of data transfer (i.e., bandwidth). Although not included in the cost analysis, the NLCHI estimated total networking costs for all EHR information systems for the province (2007) at \$24,000 per month, or \$288,000 annually. PACS will be the major network user of any EHR infrastructure, requiring 50–75% of total EHR bandwidth. Based on these estimates, the annual networking costs for PACS in the Western Authority were estimated at \$43,200. Within this context, hardware costs in the Western Authority amounted to \$2,398,790, software costs \$932,270, human resources \$400,900, and data storage \$200,000; total implementation costs for PACS in the Western Health Authority were \$3,931,960, with ongoing maintenance costs of \$229,000.

The \$2.4 million in hardware costs were financed using a 15% declining balance over 6 years (Table 6). The hardware is considered to have more value when first purchased, and as such, a higher proportion of the overall hardware costs is allocated at the beginning of the period. For the purpose of this cost per case analysis, the hardware costs are considered an ongoing expense, given that once the hardware has been fully depreciated, the PACS site will most likely need to replace and/or upgrade the equipment. Based on this assumption, the depreciation expense is included as a part of the cost per exam.

Costs in Film Environment

Operational costs in the film environment and the number of exams filmed for years 2003/2004–2006/2007 are presented in Table 7. Given the changes in MIS, the 2004/2005 fiscal year was chosen as the base year for reporting the cost per

exam in the film environment. Note that some capital costs in the film environment are not factored in when estimating cost per exam. This is because some existing equipment (e.g., computed radiography) used to produce the exam in film is basically the same equipment needed to produce the exam in PACS. This equipment was also excluded when estimating costs per exam in the PACS environment. Some capital costs are included in the PACS environment, given these costs are related to communications and storage, not exam generation (see Tables 7 and 8).

Operational Costs in PACS Environment

Operational costs in the PACS environment and the number of exams digitized for years 2003/2004–2006/2007 are presented in Table 8. As there was still residual film in 2006/2007 and because 2007/2008 was the first full year for all PACS service contracts, the 2007/2008 fiscal year was chosen as the base year for reporting the cost per exam in the PACS environment.

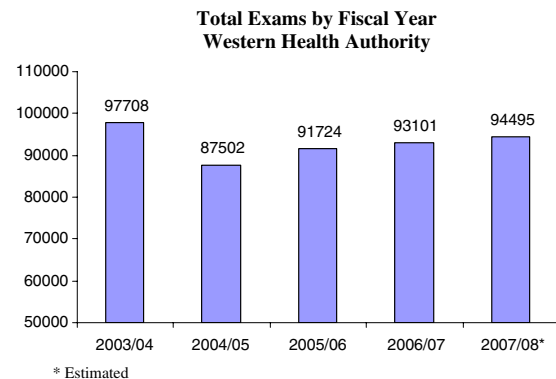
**Fig 1. Total exams by fiscal year Western Health Authority.**

Table 5. PACS Implementation Costs Western Health Authority

		Actual
	Core PACS hardware	\$351,970
	DICOM print server and integration fees	\$13,980
	Diagnostic, clinical and QC workstation—hardware	\$737,060
	DICOM gateways	\$176,280
	RIS/PACS brokers	\$76,800
	CR&DR	\$1,042,700
PACS hardware	Total	\$2,398,790
	Core PACS software	\$298,040
	Workstation—software and integration fees	\$528,610
	Web servers, software licenses, and integration fees	\$105,620
PACS software	Total	\$932,270
HR	PACS vendor	\$400,900
Other	Data storage	\$200,000
Total costs		\$3,931,960
Annual maintenance costs \$229,000		

Implementation Costs in PACS Environment

Table 9 presents the implementation costs (hardware and software depreciated) for PACS incurred in the Western Health Authority over the period 2004/2005–2007/2008. Total implementation costs over this 4-year period were \$2,433,811.

Table 10 presents the average cost per exam in the film environment compared to the PACS environment. The estimated cost per exam in the film environment is provided for both 2003/2004 and 2004/2005. As previously noted, 2004/2005 was chosen as the baseline year for cost per exam in film, given changes in MIS reporting came into effect this year. The comparative year for PACS would be 2007/2008, as the majority of the PACS implementation was completed during 2006/2007.

The operational cost (nonadjusted) per exam in the film environment was estimated at \$7.4 (2004/2005) compared to \$7.2 in the PACS environment

(2007/2008). When the implementation costs for PACS were included, the cost per exam in the PACS environment in 2007/2008 increased to \$13.2. Adjusting costs per exams based on a 4% annual inflation rate results in the cost per exam in the film environment being estimated at \$9.5 (2004/2005) compared to \$11.8 in the PACS environment (2007/2008). In choosing a 4% inflation rate, several factors were considered. Generally, we can expect wage inflation to approximate 3% to 3.5% per year, whereas drugs and medical/surgical supplies can experience inflation around 10% per year, and general inflation is about 2.0% per year. While it can be expected that most ROI models would use a 3–31/2% inflation rate (as wages are the predominant driver in expenses), a more robust rate of 4% was chosen for the PACS ROI in the Western Health Authority to minimize the risk of underestimating increasing PACS capital costs.

Table 6. PACS Hardware Depreciation Schedule Western Health Authority

Year	Book value—beginning	Rate (%)	Depreciation expense	Book value—ending
1	\$2,398,780	15	\$359,820	\$2,038,970
2	\$2,038,970	15	\$305,850	\$1,733,120
3	\$1,733,120	15	\$259,970	\$1,473,150
4	\$1,473,150	15	\$220,970	\$1,252,180
5	\$1,252,180	15	\$187,830	\$1,064,350
6	\$1,064,350	15	\$159,650	\$904,700

Table 7. Film Environment Costs Western Health Authority

Indicators	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008 ^a
Exams					
Total exams	97,708	87,502	91,724	93,101	94,495
Total film	97,708	87,502	72,254	1,606	0
% Film	100	100	79	2	0
Film costs					
Master and insert bags (\$)	29,909	31,737	32,460	18,577	0
Other paper expenses (\$)	0	0	0	0	0
Film (\$)	324,892	376,950	325,401	23,378	0
Laser film (\$)	0	0	0	0	0
Processing chemicals (\$)	22,507	16,348	12,032	2,184	0
Processor, laser maintenance (\$)	0	0	0	0	0
Courier/taxi (\$)	13,613	15,501	20,456	9,058	0
Off site storage (\$)	0	0	0	0	0
Total supplies (\$)	390,921	440,536	390,349	53,197	0
Human resources					
Film librarians (\$)	128,333	128,333	132,183	87,524	43,762
Dark room staff (\$)	80,624	80,624	83,043	21,383	0
Total HR costs (\$)	208,957	208,957	215,226	108,907	43,762
Total film costs (\$)	599,878	649,493	605,575	162,104	43,762

HR human resource^aEstimated**Table 8. PACS Environment Costs Western Health Authority**

Indicators	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008 ^a
Exams					
Total exams	97,708	87,502	91,724	93,101	94,495
Total PACS (digital)	0	0	19,470	91,495	0
% Digital	0	0	21	98	100
PACS costs					
PACS consumables costs					
CD production (\$)	0	0	25	100	100
Consumables costs total (\$)	0	0	25	100	100
Equipment and service costs					
Computed radiography (communication upgrades) (\$)	0	0	0	61,215	149,756
Site PACS services (\$)	0	0	0	161,067	298,623
Local image maintenance (\$)	0	0	0	0	55,020
Network service contract (\$)	0	0	0	62,500	62,500
Equipment/service costs total (\$)	0	0	25	284,782	565,899
Human resources					
PACS coordinator (\$)	0	0	32,502	65,004	68,976
PACS support staff (\$)	0	0	6,250	0	0
BioMed (\$)	0	0	12,499	6,250	0
HR total (\$)	0	0	51,251	71,254	68,976
PACS costs total (\$)	0	0	51,276	356,136	634,975

HR human resource^aEstimated

Table 9. PACS Implementation Costs (Hardware/Software Depreciated) Western Health Authority

Indicators	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008 ^a
	Implementation costs				
Number of exams	97,708	87,502	91,724	93,101	94,495
Human resources (\$)	0	175,000	400,900	0	0
Software (straight line method over 3 years) (\$)	0	0	310,757	310,757	310,757
Hardware (15% Dep.) (\$)	0	0	359,820	305,850	259,970
Total (\$)	0	175,000	1,071,477	616,607	570,727

^aEstimated

DISCUSSION

In reporting any type of benefit of PACS, one must be careful in drawing broad conclusions from results derived from multiple studies, even if the methods and modalities under study are the same. It is important to look at various contributing factors, including the level of efficiency that existed in the film environment prior to PACS being implemented. It is logical to assume that the more efficient the film environment is, the less impact PACS will have on many of the benefit measures traditionally studied in PACS evaluations. Included in these are those measures related purely to financial benefits.²⁰ The issue with

efficiency is illustrated in a study carried out by Weatherburn et al.²¹ which investigated the rate of radiology misdiagnosis in an emergency department. The rate of misdiagnosis pre-PACS was 1.5%, whereas post-PACS was only 0.6%. This small difference raised the question: regardless if the difference is statistically significant, is it clinically significant? The 1.5% rate of misdiagnosis suggests an efficiently run film environment existed in the emergency room prior to PACS being implemented. Following the implementation of PACS, there was a statistical benefit realized, evident by the drop in misdiagnosis to 0.6%. While this drop was not deemed to be clinically significant, any efforts to increase patient safety

Table 10. Cost per Exam in Film Environment Compared to PACS Western Health Authority

Indicator	Film 2003/2004	Film 2004/2005	Film/PACS 2005/2006	Film/PACS 2006/2007	PACS 2007/2008 ^a
Film environment (operational)					
Exams	97,708	87,502	72,254	1,606	0
Expenses (\$)	599,878	649,493	605,575	162,104	43,762
PACS environment (operational)					
Exams	0	0	19,470	91,495	94,495
Expense (\$)	0	0	51,276	356,136	634,975
PACS environment (implementation)					
Software/hardware (\$)	0	175,000	1,071,477	616,202	570,726
Total exam costs					
Total cost (\$)	599,878	824,493	1,728,328	1,134,442	1,249,463
Cost per exam (operational: adjusted for inflation)					
Total exams	97,708	87,502	91,724	93,101	94,495
Operational cost/exam (\$)	6.1	7.4	7.2	5.6	7.2
Adjusted for inflation (\$)	6.1	7.4	6.9	5.1	6.4
Cost per exam (operational + implementation: adjusted for inflation)					
Implementation costs/exam (\$)	0	2.0	11.7	6.6	6.0
Total costs/exam (\$)	6.1	9.4	18.8	12.2	13.2
Adjusted for inflation (\$)	6.1	9.5	18.3	11.3	11.8

^aEstimated

must be considered important in the provision of patient care. In addition to consideration being given to the efficiency of the existing film environment, other areas requiring consideration in isolating benefits of PACS would include the redesign of workflow, facility type and size, hospital information system/radiology information system (RIS)/PACS integration, training, support staff, and patient population.¹⁹

The volume of exams performed in a site and its relationship to the expected benefits of PACS can also impact on the level of benefits achieved through introducing PACS. While installing PACS in a site that only averages 10,000 exams per year may not be a practical investment for most sites, it nevertheless raises the question as to what constitutes the necessary volume of images before an investment in PACS becomes feasible. Several studies report the number of acute care beds as an indicator of imaging volume,^{5,9,22–25} whereas others use the actual volume of exams.^{26–28} An earlier study by Bauman et al.²⁹ went as far as to state that a large PACS installation required a minimum of 20,000 examinations per year to ensure the feasibility of PACS, whereas 7 years later, Siegel and Reiner²⁷ reported the cutoff was at 39,000 exams. In classifying sites, Cartier³⁰ carried out a study in a “small” hospital that produced 15,000 exams a year, while Hayt et al.³¹ carried out a study in a “large” hospital that produced 116,000 exams per year. While these studies classified the size of a site either in relation to the number of beds or the actual volume of exams, there is no consensus on standards for such classifications. Nevertheless, such studies do raise the question as to how one interprets the benefits of PACS within the context of exam volume.

Classifying a site as a low, moderate, or high user of PACS is for the most part a subjective exercise, with no standards in place that would allow for comparisons between “like” sites. The hierarchy of exam volumes at which a site moves from one level to the next is unclear, given the impact that the volume has on workflow is directly influenced by the level of efficiency that exists in the diagnostic imaging (DI) department. It therefore would be inappropriate to assume PACS becomes feasible only after a certain threshold of exam volume is achieved. While recognizing a certain volume of exams is required to justify

implementing PACS, there are other characteristics of the site that will ultimately impact the benefits achieved. In the Western Health Authority, having a total of 112,667 exams, it was expected that financial benefits of PACS would be found. However, our analysis estimated the average an exam generated in PACS will cost \$2.65 more than one created in the film environment, supporting the argument that it can be challenging to justify the need for PACS in “low” volume sites.³²

Capital and operational costs associated with the implementation of PACS in the Western Health Authority were very costly. The most significant contributor to the cost of PACS and the main reason for not realizing a financial return on investment were equipment and maintenance costs. In the Western Health Authority, total cost of PACS was \$4.1 million, of which \$2.4 million was for hardware (58%). In addition to hardware costs, annual licensing and maintenance costs usually run about 10–15% of capital costs, which in the case of the Western Health Authority came to \$229,000 per year. One potential opportunity to reduce PACS equipment costs is for multiple sites to partner and offer a joint request for proposals, thus taking advantage of any economies of scale. However, this opportunity was not realized in Newfoundland and Labrador. The overall cost for the provincial implementation/enhancement of PACS was \$23 million, not an insignificant amount, even nationally. Yet even with this expenditure, there were no major savings realized, and the costs of the PACS equipment resulted in most hospitals in the province not achieving a return on investment. Until costs of PACS hardware, software, and licensing fees comes down in price, it is unlikely, except in the largest urban hospitals, that there will be any financial return on investment for the majority of PACS implemented in Canada.

In looking at business models, there are studies that consider PACS as an opportunity to increase revenues,^{12,33} whereas other studies investigate PACS from the perspective of costs savings.^{34–37} With respect to what costs are included in a financial analysis, they can be categorized as direct or indirect costs.³⁸ Direct costs are those immediately involved in operating the DI department and would include costs such as the film supplies, chemicals, courier fees, staff, equipment, maintenance fees, and storage space.^{6,7,39} Indirect costs would include intangibles such as enhanced patient

care, improved patient outcomes, reduced length of stay and duplicate exams, and improved clinician satisfaction.^{6,40,41} If we include other variables such as facility type, patient population, and the level of pre-PACS site efficiency in the financial model, then it is obvious that each study will have its own unique features and thus provide little in the way of opportunities for comparability with other studies.

The real challenge is not in determining revenues and/or savings, although both are important and relatively easy to measure. The challenge is determining indirect benefits of PACS that even today continues to elude meaningful measurement. That is, how can one quantify in financial terms benefits such as improved patient care or outcomes, improved access, or clinician satisfaction?

In spite of the 25 plus years of PACS research, there still is no consistent evidence that supports the financial benefits across the many diverse environments in which PACS operates. Sites having high exam volumes, inefficient film environments, and opportunities to generate revenues offer the best likelihood of achieving a financial return on investment. In contrast, the Western Health Authority had a moderate exam volume, an efficiently run film environment, and no opportunities for generating revenue. This environment resulted in the cost per case analysis in Western Health Authority concluding that unless the planning horizon is lengthy, PACS is more expensive to operate than within the traditional film environment.

While this study focused on a return on investment analysis for PACS, it is recognized that the true benefits of PACS go beyond simply financial measures. There are many other benefits of PACS that need to be considered in the broader context of patient care. Benefits such as improved efficiency and productivity, which are achieved in part through improved report turnaround times⁴²⁻⁴⁴ and immediate access to reports/images from multiple sites^{24/74, 44-50} are but two benefits of PACS considered to offset any higher costs for PACS.

CONCLUSION

Using methods of accounting generally employed in the Canadian health care system, our study found that the cost per exam in the PACS environment was \$11.8, compared to \$9.5 in the film environment.

Further, our study estimated that it will cost an average of \$2.65 more per exam in PACS than in film for the first 6 years of PACS operation. PACS was very costly to implement and to maintain in the Western Health Authority, making it difficult to justify PACS based solely on a financial costing model. Other benefits, such as enhance patient care, need to be considered when evaluating the overall benefits of PACS. The primary reasons for not achieving a return on investment for PACS in many sites under study was a combination of low exam volume, a preexisting efficient film environment and the high costs for PACS hardware, software, and ongoing maintenance.

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