# The Reality of Picture Archiving and Communication Systems (PACS): A Survey

Roger A. Bauman and Guenther Gell

Toward the end of 1997 vendors were succeeding in installing picture, archiving and communication systems (PACS) in larger numbers. It was hard to separate fact from fiction at times. This survey was undertaken by 2 members of the academic community to confirm what was operational, how well the installed systems worked, and what they were doing. Fax questionnaires were sent to nearly 1,000 facilities worldwide to identify PACS of any size in clinical operation on a date certain, February 1, 1998. A total of 177 PACS were identified. Facilities furnished responses during the first survey period from May 1 to November 1, 1998. A second survey, done in February and March of 2000, sought long-term follow-up data. Many systems operated 5 or more types of modalities. Computed tomography (CT) was the most common modality type at 83%, but the distribution of the rest held surprises. There also was an unexpectedly large use of soft copy reading and filmless operation in 1998. Clear trends toward increased use of computed radiography and digital radiography and a significant expansion on the percentage of all of a facility's examinations on the PACS were seen over the 2 years. Satisfaction with original PACS vendors was relatively high. Eighty-nine percent remained with their original vendor. Only 10 sites reported they changed vendors, and 4 facilities said they abandoned their system. The users reported their expectations of the PACS had been met in 81% of cases. Some (65%) declared their systems were cost effective. The most striking response was that 97% of the users would recommend PACS to others.

Copyright © 2000 by W.B. Saunders Company

KEY WORDS: radiology, computers, picture archiving and communication systems (PACS), digital imaging, survey.

WHEN PEOPLE BEGAN to envision picture, archiving, and communication systems (PACS) about 20 years ago, the computer hardware then existing was not up to the task. Demonstration projects in academic institutions began to explore the vision. Hardware limitations like the speed and capacity of disk drives, standard network protocols, and the limited resolution and contrast of electronic displays were very real barriers to clinical operations.

Most of these efforts were done internally at academic institutions, although some were in cooperation with industry. Smaller projects aggregated into larger ones, and, at last, some PACS emerged. In 1993 a survey found 13 large PACS,<sup>1</sup> and a 1995 survey found the number of large PACS had grown to  $23.^{2,3}$  The definition of large PACS used in those and this survey can be found in the discussion section.

The later 1990s in particular saw very large gains in the technical performance of central processing units; RAM memory; disk storage speeds and capacity; the broad availability of faster standard networks like FDDI, ATM, and fast Ethernet; and, more recently, improvement in long-term archive capacities and speed. Also important were improvements in the quality of software, in the interfaces with other information systems, and advances in the DICOM and HL7 standards. These advances occurred as prices decreased, and many commercial vendors began to offer PACS.

At large radiology meetings users would wonder if they were the only department that had not yet ordered a PACS. Further, these systems operated nearly without flaw, it would seem. Where were all those other hospitals getting large sums of money for PACS in a time of health care underfunding? How real are these impressions? How real is PACS? This study was undertaken to address such questions as well as to ascertain what features were in clinical use on both older and more modern PACS.

It was decided to survey a large group of facilities without attempting to locate every last PACS. Only systems in actual clinical operation on a certain date, February 1, 1998, would be eligible. Systems of any size in hospitals of all sizes and outpatient facilities would be included. The survey was designed with 2 inquiry periods. The first was conducted from 3 to 9 months after the February 1 date to gather initial impressions and judgments.

Copyright © 2000 by W.B. Saunders Company 0897-1889/00/1304-0006\$10.00/0 doi:10.1053/jdim.2000.17804

From Massachusetts General Hospital, Boston, MA, and the Institute for Medical Informatics, Statistics and Documentation, University of Graz, Graz, Austria.

Address reprint requests to Guenther Gell, PhD, Institute for Medical Informatics, Statistics and Documentation, University of Graz, Engelgasse 13, A-8010 Graz, Austria.

	ଟ	rd World	wide PA(	<b>SSULVEV</b>	<u>as of Fe</u>	bruary 1.19	<u> 368</u>	
1. What is your hosp 2. Did you have a PA	ital total bed size? CS in clinical operation install one within to	Acution on February 1,	e beds only?	Total be INo D If y	d size in entire er ou do NOT hav	rterprise system?	stop here and fa 99-2387. Thanks	ix this page
	4. Which does your 5. Was your PACS	r PACS serve? F	Answer al ladiology only?	I questions for F	ebruary 1, 199 Ny? 🔲 Your en ommercial? 🗍	8 terprise members only Commericial only?⊡	2 Other?	
<u>,                                     </u>	6. Who is your ma 14. Total annual r	iin PACS vendor number of exams			7. Who is your F 8. Do you do tele	PACS integrator?	D	
		For thi	s modality sp	scific data use a	oproximations	if necessary.		
R E-TURN	Modality	Total Number of these devices?	Per cent of modality on PACS?	Percent of soft copy primary reading?	Percent of filmless studies?	Percent stored in long term archive?	Compression ratio in long term archive?	Total annual no.exzms this modality?
T-AX	U	8						
BLCCK	CT	-						
	Digital angiograph	····· A						
	Digital	λ		-				
	Mammograph	Yr						
	X	æ						
	Z	Z						
	D	S						
	Your name email·		Tel			FACIL	INAN YTI	
<ol> <li>9. Are display termi</li> <li>10. How many <u>disp</u></li> <li>11. Has your PACS of</li> </ol>	nals outside of radiol lav terminals outside t met your expectation ost effective? Yes	logy connected vi s of radiology ? ons? Yes □ No⊡	a: DICOM?	Intranet? Cther Iy? How these are diag workstations?	P □ P □ P □ P □ P □ P □ P □ P □ P □ P □	ADDE	15×5	
13. Would you reco	unsolved or vexing	thers? Yes D No problems.	Q					

Fig 1. This is the survey form used in the first survey period, that is, 3 to 9 months after the February 1, 1998. It usually was faxed with a cover sheet. The name and telephone of the recipient (above question 9) and the facility name and address (in the lower right hand corner) usually were printed on the form from the database. The form also served as both a cover sheet and the message as a return fax, because the block on the left contained the name and fax number of one of the authors.

		liber of l'aclifices of	urveyed and Those w	Itin I AGO OF ANY SIZE	
	Facilities Surveyed	Surveys Returned	Percent Responding	PACS Found Operating on 2/1/98	Will Install PACS in 2 Years
Asia	15	14	93	13	1
Australia	1	1	100	1	0
Europe	550	72	13	41	18
North America	431	276	64	122	39
Totals	997	363	36	177	58

Table 1. Number of Facilities Surveyed and Those With PACS of Any Size

NOTE. The right-hand column are facilities that did not have a PACS, but they reported they plan to get one within 2 years.

The second survey was done 2 years later to detect changes and long-term successes or lack thereof.

### MATERIALS AND METHODS

Hospitals and other facilities to survey were identified in several ways. Vendors were asked for lists of active systems. The authors also relied on personal knowledge and the advice of colleagues as well as on information gathered at meetings. A significant help was a listing of hospitals in the United States furnished by a marketing group.

The surveys were conducted mainly by fax. Some e-mail inquiries also were used. Obtaining the fax number or the e-mail address and name of the correct individual at each facility was nontrivial, time consuming, and expensive. The facility telephone numbers originally furnished often had changed because of the widespread creation of new area codes throughout the United States.

All respondents were asked 3 initial questions: facility bed size, did they have an operational PACS on February 1, 1998, and, if not, did they plan to acquire a PACS?

Only those with an operational PACS were asked to complete the full survey form (Fig 1). Surveys were returned, usually by fax, and the responses were entered into a database for analysis.

The data furnished on the surveys were accepted without any special validation. Special further inquiries by us were usually not done, limited to rare instances of outlier responses. In one case, 10 of 83 facilities furnishing data on filmless operation were excluded from analysis because they did not also report soft copy interpretation of the filmless modality types. In reading and interpreting the survey results, remember that no information is included from facilities that did not return the survey form.

#### RESULTS

### Information in the Survey

Just under 1,000 facilities were surveyed (Table 1). A total of 363 of 997 surveys were returned, a

36% return rate. A total of 177 PACS were identified. In addition, 58 departments indicated they planned to acquire a PACS within 2 years. The distribution of the 177 systems in clinical operation on February 1, 1998 and of those planned is shown in Table 1.

Facilities were subdivided by the number of beds into small, medium, or large hospitals or outpatient facilities (no beds). Enterprise systems, that is, organizations with 1 or more hospitals and outpatient facilities, were ranked according to total bed capacity. The distribution of the 177 PACS by facility type is shown in Table 2 by continent.

# INFORMATION ABOUT THE PACS

Respondents were asked to characterize their systems in several ways. One question dealt with whether the PACS was accessible only within radiology or whether it served only 1 hospital or an enterprise organization. This distribution of systems by continent is in Table 3.

Note that data from only 124 facilities are presented in Table 3. Not all surveys included responses to all questions. In Table 3 and the following tables all appropriate data furnished in the survey are used, and the number of facilities providing it is shown.

How the system was developed is conveyed in Table 4. Was the development entirely within the institution (in-house), entirely commercial, or a mix of the 2 approaches?

The respondents worldwide reported 27 differ-

	Table 2. Num	ber of PACS Found by	Continent and Facility Ty	be	
	Outpatient Facility (no beds)	Small Hospital (0-199 beds)	Medium Hospital (200-499 beds)	Large Hospital (500 + beds)	Totals
Asia	0	2	3	8	13
Australia	0	0	1	0	1
Europe	0	2	10	29	41
North America	18	12	49	43	122
Totals	18	16	63	80	177

able 2. Number of PACS Found by Continent and Facility Type

	Radiology Only	Hospital- Wide	Enterprise	All
Asia	2	9	0	11
Australia	0	1	0	1
Europe	10	20	5	35
North America	16	36	25	77
Totals	28	66	30	124

ent PACS vendors! The numbers of facilities by vendors is shown in Table 5 by continent. The number of vendors in the table is lower because of mergers. Note that any vendor might have other facilities that either were not surveyed or that did not answer the survey.

The respondents were asked for the number of display terminals outside of and inside the radiology department and how many interpretation workstations there were in the radiology department. The means and ranges of the number of terminals are presented by hospital size and by continent in Table 6. Whether the terminals were connected via DICOM, Intranet, or another method is shown in Table 7.

### Information on PACS Operations

A total of 133 facilities furnished data about aspects of the modality types that comprise their PACS. The survey requested the percentage of each of 8 modality types on a PACS. In the earlier 1993 and 1995 surveys many modality types were reported to have only a portion of the total examinations for a modality type actually on the PACS. It was notable that now most modality type percentages reported were at 100% on the PACS. Fewer than a quarter of all facilities had any modality types at lower percentages and then usually only 1 to 3 such modality types with others at 100%. Less than 5 reported PACS with only partial modality types on their PACS.

The 8-modality types queried in roughly alphabetical order were computed radiography (CR), computed tomography (CT), digital angiography (DA), digital fluoroscopy (DF), magnetic resonance imaging (MR), nuclear medicine (NM), ultrasound (UL), and mammography.

In Table 8 the number of different modality types that are connected to the PACS are the groupings shown in the left-hand column. For each

	Outpatient Facility (no beds)	Small Hospital (0-199 beds)	Medium Hospital (200-499 beds)	Large Hospital (500 + beds)	All Facility Types
Asia (n)	0	2	4	6	12
Internal development only (%)	-	0	75	0	25
Mixed development (%)	—	0	0	50	25
Commercial vendor only (%)	-	100	25	50	50
Australia (n)	0	0	1	0	1
Internal development only (%)	-	_	0	_	0
Mixed development (%)	-	—	0		0
Commercial vendor only (%)	-	—	100	_	100
Europe (n)	0	2	7	25	34
Internal development only (%)	_	0	0	16	12
Mixed development (%)	-	50	0	64	50
Commercial vendor only (%)	_	50	100	20	38
North America (n)	8	7	41	30	86
Internal development only (%)	0	14	7	0	5
Mixed development (%)	0	29	37	33	31
Commercial vendor only (%)	100	57	56	67	64
Totals (n)	8	11	53	61	133
Internal development only (%)	0	11	15	8	8
Mixed development (%)	0	33	37	55	35
Commercial vendor only (%)	100	78	78	53	56

Table 4. PACS	Development	Mode
---------------	-------------	------

NOTE. n = number of facilities reporting data.

# THE REALITY OF PACS: A SURVEY

Vendor	Total PACS Reported	Asia	Australia	Europe	North America
ADAC	1				1
Agfa	21				21
Agfa Sterling	4				4
ALI	3				3
GE Applicare	1			1	
Canon	2				2
Data General	1				1
DR Systems	14				14
Dynamic Imaging	2				2
Emed (Access)	3				3
General Electric	22	3		2	17
Hyundai	1	1			
TIANI	4			4	
Image Devices	1			1	
КСС	1	1			
Kodak Cemax-Icon	15			4	11
Miscom	1			1	
Nippon Electric Company	2	2			
Philips Medical Systems	7			6	1
Rogan Medical Systems	2			1	1
Siemens	23	1	1	10	11
Siemens & Agfa	1			1	
Siemens & Fuji	1			1	
Siemens & Philips & Kodak	1				1
Toshiba	3			2	1
VA Medical - VISTA	6				6

Table 5.	Vendors as	Reported	bv the	Facilities	Surveyed
1 4010 0.	1011010 00	noponou :	.,	1 40/112100	00.10,00

NOTE. Respondents named 27 vendors in 1998. The number of vendors shown is smaller because of subsequent mergers.

Table 6.	PACS	Display	/ Terminals	and	Workstations	by	Location

	Sma	all Hospital (0-	199 beds)	Mediu	m Hospital (20	0-499 beds)	Larg	e Hospital (50	0 + beds)
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Asia	-	n = 1			n = 4			n = 6	
Outside of radiology	3.0	3	3	43.8	2	128	42.5	0	155
In radiology	2.0	2	2	7.5	2	20	21.5	8	31
Workstations in radiology	1.0	1	1	4.3	3	6	10.2	2	20
Australia					n = 1				
Outside of radiology	_	-	_	45.0	45	45	-	-	_
In radiology	_		_	20.0	20	20	_		
Workstations in radiology	-	-	-	20.0	20	20	-	-	-
Europe	n = 2			n = 7			n = 23		
Outside of radiology	2.5	2	3	43.3	1	146	38.5	0	150
In radiology	5.0	5	5	12.7	1	24	15.1	2	80
Workstations in radiology	2.5	2	3	10.1	1	2.4	14.3	2	130
North America		n = 8			n = 38			n = 33	
Outside of radiology	42.3	0	135	43.5	0	400	279	0	7,000
In radiology	5.6	1.0	15	7.3	1	20	16.2	2	55
Workstations in radiology	2.9	0	8	5.0	0	16	12.5	1	50

NOTE. n = number of facilities reporting data. The PACS reporting 7,000 display stations uses an Intranet to connect PCs in several hospitals and outpatient facilities in their large Enterprise system.

	Outside of R	adiology	
	Small Hospital (0-199 beds)	Medium Hospital (200-499 beds)	Large Hospital (500 + beds)
Asia (n)	1	5	5
Via DICOM (%)	0	40	40
Via Intranet (%)	0	40	40
Other (%)	100	20	20
Australia (n)	0	2	0
Via DICOM (%)	0	50	0
Via Intranet (%)	0	0	0
Other (%)	0	50	0
Europe (n)	2	8	22
Via DICOM (%)	0	38	59
Via Intranet (%)	50	13	36
Other (%)	50	50	5
North America (n)	5	48	30
Via DICOM (%)	0	42	63
Via Intranet (%)	20	25	23
Other (%)	80	33	13
Totals	8	63	57

Table 7. PACS Terminal Connection Methods

NOTE. n = number of facilities reporting data.

modality type (eg, CR, CT) the percentage of PACS in that category that have 1 or more of each modality type present is shown in the column for that modality type and group. More than 75% of the devices of a modality type must be on the PACS for it to be counted. The numbers on the bottom line are the total number of each modality type reported on any PACS.

A total of 126 facilities furnished the percent of

cases archived in a long-term archive by modality type. One hundred three (83%) archived all or almost all of their studies, meaning that 90% to 100% of every or almost every modality type on the PACS was archived. Sixteen more (13%) archived a significant part of their cases, and 6 others archived only some examinations. Note, we cannot say how much long-term archiving is being done by facilities that did not furnish these data.

Long-term archive compression ratio information was furnished by 144 facilities. Usually data were given for some but not all of the modality types in use. Different ratios for different modality types were not infrequent. Users of 3 vendors reported their vendor used no compression. Sixteen further respondents reported compression ratios in the lossless range. This is 70% (19 of 27) vendors that did not use lossy compression. The remaining 8 vendors were reported to use no or lossless compression for most modality types and irreversible compression for a few modality types with ratios ranging from 10:1 to 22:1 including DR Systems, Emed-Access, General Electric, Hyundai, KCC, Nippon Electric Company, Philips Medical Systems, and Siemens. Bear in mind that the respondents might have made errors in the ratios. These data were not furnished by, nor confirmed with, the vendors.

Primary interpretation of imaging studies displayed on workstation monitors, often called soft copy reading, was queried. Six departments reported reading 100% of 7 modality types from soft copy. The 100% soft copy reading of various

PACS Grouped by the No. of Included Modality Types	No. of Facilities	CR (%)	CT (%)	DA (%)	DF (%)	MR (%)	NM (%)	US (%)	Mammography (%)
8	2	100	100	100	100	100	100	100	100
7	17	100	100	100	100	100	94	100	6
6	26	85	100	69	96	96	50	96	0
5	28	86	100	57	61	82	43	57	7
4	18	89	100	6	11	89	11	94	0
3	10	30	90	10	30	70	10	60	0
2	21	33	38	5	5	0	48	19	0
1	11	27	18	9	0	27	9	9	0
Totals	133	71	83	43	50	70	43	66	4
No. of each modality type on all PACS	133	94	110	57	67	93	57	88	5

Table 8. Modality Type Percentages on PACS Grouped by the Number of Types of Modalities

NOTE. The PACS are grouped by the number of modality types they have in the left-hand column. The percentage of each modality type for that PACS category is shown in the modality type column. The number of each modality type on all PACS is shown at the bottom.

Table 9. Number of Modality Types Read 100% From Soft Copy by Facility

No. of Modality Types	Outpatient Facility (no beds)	Small Hospital (0-199 beds)	Medium Hospital (200-499 beds)	Large Hospital (500 + beds)
7	0	0	4	2
6	0	0	4	4
5	1	1	5	4
4	0	0	2	3
3	1	2	4	4
2	1	0	4	8
1	1	3	6	16
Totals	4	6	29	41

numbers of modality types according to facility size is in Table 9. The distribution by continent is shown in Table 10.

The percentage distribution of 100% soft copy reading of modality types and subdivided according to the number of modality types so read is presented for all responding facilities in Table 11.

Five departments reported that 100% of their mammograms were on their PACS, 3 in Asia, 1 in Europe, and 1 in North America. One Asian and 1 European department reported 100% soft copy of reading of mammograms. One other European facility reported reading 20% of their mammograms by soft copy. Lastly, only 1 department in Asia reported 100% filmless mammography. There is no information from any of these facilities on how the mammograms were acquired or read from soft copy.

Some PACS began "filmless" operations before the 1995 survey. Producing and storing images without the use of film requires soft copy interpretation. The further cost savings of filmless operations make it attractive. Yet, in 1998, only a minority of the responding facilities reported filmless operations. The respondents were asked to furnish the percentage of each of 8 modality types that were filmless in their facility. Film-based images made for extrahospital use, for operating room use, or other such secondary purposes were allowed.

In this study, facilities reporting filmless studies were divided into 5 groups using the criteria below: completely filmless, almost filmless, largely filmless, moderately filmless, and some filmless studies.

 A facility with 7 or 8 99% or 100% filmless modality types was rated as "completely filmless."

- A facility with 6 or more modality types filmless at 75% or more was rated as "almost filmless."
- The "largely filmless" group required 4 or 5 modality types at 75% or more.
- A facility with 3 modality types filmless at 75% or more was rated "moderately filmless."
- The "partially filmless" group reported sometimes lower percentages in at least 3 modality types.
- The "some filmless" was used for facilities reporting some filmless work in 1 or more modality types.

The distribution of filmless operations reported by 73 facilities is shown in Table 12. Of course, any PACS might be "filmless" for 1 or more modality types. These categories attempt to quantify the results with reference to how "filmless" a department is. They are not likely to work well for outpatient facilities and some smaller hospitals. Note that a small hospital or an outpatient facility with only 1 or only a few modality type(s) might actually be "completely filmless" but be classified less so by these criteria. No information on how many modality types existed in a facility was solicited.

The percentage distribution of the 75% to 100% filmless modality types in each of the groups is shown in Table 13.

A total of 133 facilities gave yes or no answers to whether they did teleradiology. Their distribution is presented in Table 14. There is no information on whether the other facilities did teleradiology.

### Large PACS

The criteria for "Large PACS" (see Discussion) used in the 1993 and the 1995 survey were applied

Table 10.	Number	of Modality	Types Read	100% from	Soft
		Copy by C	ontinent		

No. of Modality Types	Asia	Australia	Europe	North America	All
7	1	1	2	2	6
6	1	0	2	5	8
5	1	0	5	5	11
4	0	0	1	4	5
3	3	0	2	6	11
2	0	0	3	10	13
1	2	0	5	19	26
Totals	8	1	20	51	80

PACS Grouped by the Number of Included Modality Types	No. of Facilities	CR (%)	CT (%)	DA (%)	DF (%)	MR (%)	NM (%)	US (%)	Mammography (%)
8	0	_	_					_	_
7	6	100	100	100	100	100	83	83	17
6	8	88	100	100	88	63	75	100	13
5	11	73	91	82	82	45	18	64	0
4	5	40	60	0	20	80	40	80	0
3	11	36	55	0	9	55	18	64	0
2	13	38	46	8	8	15	31	54	0
1	26	35	4	0	4	12	12	31	0
Totals	80	51	50	30	33	39	30	58	3
No. of soft copy read modality types on all PACS		41	40	24	26	31	24	46	2

Table 11.	Modality	Types Read	100%	From	Soft Copy

	Outpatient Facility	Small Hospital	Medium Hospital	Large Hospital	
	(no beds)	(0-199 beds)	(200-499 beds)	(500 + beds)	All
Asia	0	1	2	1	4
Almost filmless	0	1	1	1	3
Some filmless	0	0	1	0	1
Australia	0	0	1	0	1
"Completely" filmless	0	0	1	0	1
Europe	1	1	3	12	17
Completely filmless	0	0	0	1	1
Almost filmless	0	0	2	2	4
Moderately filmless	0	0	0	6	6
Partially filmless	0	1	0	3	4
Some filmless	1	0	1	0	2
North America	6	2	22	21	51
Completely filmless	0	0	2	0	2
Almost filmless	0	0	1	2	3
Largely filmless	1	1	6	1	9
Moderately filmless	0	0	1	3	4
Partially filmless	1	0	3	5	9
Some filmless	4	1	9	10	24
Totals	7	4	28	34	73

NOTE. The categories of filmless operation are defined in Results.

Table	13.	Distribution	of 75% to	100%	Filmless	Modality	Ty	pes by	Categ	ory

How Filmless?	No. of Facilities	CR (%)	CT (%)	DA (%)	DF (%)	MR (%)	NM (%)	US (%)	Mammography (%)
Completely	4	100	100	100	100	100	100	100	25
Almost	5	100	100	80	80	80	80	100	0
Largely	13	77	100	69	92	54	23	77	0
Moderately	4	75	50	0	50	0	25	100	0
Partially	16	25	19	6	0	13	19	75	0
Some	31	19	10	0	6	16	6	39	0
Totals	73	44	41	25	33	30	23	64	1
Number of each 75%+ filmless modality type									
on all 73 reporting PACS		32	30	18	24	22	17	47	1

	Outpat (ne	ient Facility o beds)	Small Hospital (0-199 beds)		Mediu (200	Medium Hospital Lar (200-499 beds) (5		Large Hospital (500+ beds)		All Facilities	
	No. Reporting	Percentage Using Teleradiology	No. Reporting	Percentage Using Teleradiology	No. Reporting	Percentage Using Teleradiology	No. Reporting	Percentage Using Teleradiology	No. Reporting	Percentage Using Teleradiology	
Asia	0	0	1	100	3	33	7	43	11	45	
Australia	0	0	0	0	1	100	0	0	1	100	
Europe	0	0	2	0	7	43	25	56	34	50	
North											
America	9	78	6	100	42	79	30	77	87	79	
Totals	9	78	9	78	53	72	62	65	133	69	

Table 14. Teleradiology Operations

to the 1998 responses. Table 15 shows the growth that has occurred.

### Information on User Satisfaction

The initial survey asked 3 questions about the PACS (Table 16). Has your PACS met your expectations? Is your PACS cost effective? Would you recommend PACS to others?

The almost unanimous recommendation of PACS to others is remarkable. These responses were obtained 3 to 9 months after the set date of February 1, 1998 for clinical operations. Thus, all respondents had a minimum of 3 months of actual experience and some much more. Note that even those whose expectations were not met and those who found their system not to be cost effective did recommend PACS to others. Only 4 facilities (<3%) would not recommend PACS to others. One of these from Asia did rate their PACS both cost effective and as meeting their expectations.

### The Second Survey—2 Years Later

The second survey posed 10 questions (Fig 2). It addressed long-term user satisfaction levels with their PACS and their vendors, the number of radiographic and the number of total examinations on the PACS in 1998 and in 2000, and how images were or were not made available electronically to

Table 15. Large PACS Identified in 3 Surveys

	· · · · · · · · · · · · · · · · · · ·			
	1993 Survey	1995 Survey	1998 Survey	
Asia	1	4	7	
Australia	0	0	1	
Europe	4	6	16	
North America	8	13	41	
Totals	13	23	65	

clinicians. More than half (n = 92) of the identified PACS responded to the second survey.

# Changes in the Use or Size of the PACS After 2 Years

The replies are shown in Table 17. Four of the 5 PACS unchanged in size already handled 100% or almost 100% of their examinations on the PACS in 1998. The other was quite small.

Most of the 5 facilities that abandoned or decreased the use of PACS had older systems that apparently did not or would not expand well. Only one of these five responded to the second survey question on recommending PACS to others. That facility, although they had abandoned their system, still recommended PACS to others!

The number of examinations for each modality type and the percent of each modality type on the PACS were requested in the 1998 survey. Answers were inconsistent and occasionally hard to interpret. In 2000 the users were asked what percentages of all examinations (except mammography) were on the PACS in February, 1998 and in 2000. Twenty-eight reported that less than 35% of their examinations were on the PACS in 1998. Thirteen of this group increased less than 30% in 2000. The other 15 increased the percentage of their examinations on the PACS from between 35% to 90%. A middle group beginning with 35% to 89% numbered 34 systems. Ten of these changed little over

Table 16. Answers to 3 Questions by PACS Owners

	No. of Responses	Yes	% Yes Responses	No
Met your expectations?	145	118	81	27
Cost effective?	127	83	65	44
Recommend to others?	148	144	97	4

Dear	Colle	eague,
------	-------	--------

Thank you for your response to our survey of PACS operational in February of 1998. That first survey round was done 4-9 months after that date to ensure you had had some experience. We are ready to publish the survey results as soon as we add the longer term follow-up responses in round 2 about which I am now writing.

# Please answer these few questions and return them to us.

A. Since February 1998 have you: Abandoned your PACS? Expanded its size somewhat?	Decreased its use? Expanded it quite a bit?
B. Have you changed vendors?	
C. How satisfied are you with your original vendor Dissatisfied Mixed feel Satisfied Very Satis	ings fied
D. Roughly what percentages of all studies (other in February of 1998?Now?	than mammography) were on your PACS
E. In 1998 roughly what percentage of your plain to What percentage is now done by CR and DR?	film radiographs were done by CR?
F. Are only relevant images selected for long term	n archiving? 📋 Yes 🛛 🗌 No
G. Are images available to clinicians in electronic not at all  Intranet (Web Browser) Inter Other	form: COM Protocol ernet (Web Browser)
H. Do you select a relevant subset of images from	a study for clinician viewing? 🗌 Yes 🛛 🗌 No
I. Has your PACS met your expectations?	es 🗌 No
J. Is your PACS cost eddctive now?	No
K. Would you recommend PACS to others? Ye	s 🗌 No
Günther Gell, Ph.D. Institute for Medical Informatics, Statistics and Documentation Engelgasse 13, A-8010 Graz, Austria Tel.: +43 316 385-3201 Fax.: +43 316 385-3590	Roger A. Bauman, MD Journal of Digital Imaging Harvard Medical School Boston, MA Tel.: +1 781-729-2387 Fax.: +1 781-729-1651
e-mail: quenther.gell@kfunigraz.ac.at	e-mail: di@MEDIAONE.NET

Fig 2. This is the survey form usually faxed to facilities with PACS in February or March of 2000 for the second, long-term survey.

Table 17. Changes in PACS Use or Size After 2 Years

	No. of Responses	Percentage of the Group
Have you abandoned your PACS?	2	2.2
Have you decreased its use?	3	3.3
Is its size unchanged?	5	5.4
Have you expanded it somewhat?	43	46.7
Have you expanded it significantly?	39	42.4
Total	92	

the 2 years. The remaining 24 all increased to 80% to 100% in 2000. The high-end group of 19 PACS began with 90% or higher coverage. Twelve of these began with 98% or greater coverage. Five of the other 7 reached that level in 2000. Overall, only 24% of the facilities had greater than 80% of their department examinations (excluding mammography) on the PACS in 1998. Two years later that percentage had doubled to 56%.

Plain radiographic examinations constitute 70% to 80% numerically of the total examinations in some departments. The percentage of these studies on the PACS also was queried. They do pose difficulty in handling them digitally. Identification problems and labor costs virtually rule our digitizing film-based studies.

In 1998 only 39 (46%) of 85 facilities reported 50% or more of their plain radiographic studies to be in digital form on their PACS. The greater part of the majority of facilities had less than 15% of their cases on the PACS. A move to CR and DR is evident in the 2-year period, as in 2000, 45% of the PACS had 90% or more on the PACS with an additional 36% at over 50%, a total of 81% with more than 50%.

### Vendor Satisfaction After 2 Years

A total of 91 users indicated their satisfaction level with their *original* vendor (Table 18). Users also were asked if hey had changed vendors since

Table 18. Satisfaction With the Original Vendor After 2 Years

How Satisfied Are You With Your ORIGINAL Vendor?	No. of Responses	Percentage of the Group
Dissatisfied	4	4.4
Mixed feeling	27	29.7
Satisfied	46	50.5
Very satisfied	14	15.4
Total	91	

Table 19. Methods of Making PACS Images Available to Clinicians

Are Images Available to Clinicians in Electronic Form?	No. of Responses	Percentage of the Group
Via DICOM protocol	53	58.2
Via Intranet (web browser)	13	14.3
Via Internet (web browser)	2	2.2
Other	8	8.8
Not at all	15	16.5
Total	91	

1998. Eighty-nine percent (n = 81) had retained their original vendor. Ten facilities reported they had changed vendors. Their satisfaction with the original (the replaced) vendor in 2000 was dissatisfied in 3 cases, mixed feelings in 4 cases, satisfied in 1 case (?), and very satisfied in 2 cases (?).

### Images for Clinicians

Eighty-four percent of respondents did make images available to clinicians in electronic form (Table 19). Twenty-four percent of facilities reported that they did select a subset of images for clinician viewing.

### DISCUSSION

This survey has confirmed the presence of a large number of PACS worldwide. Although extensive, this survey was not meant to be exhaustive. Generally, only 2 attempts were made to obtain responses from a facility. Some facilities known to have PACS chose not to respond.

Certainly, many PACS have been installed since the survey cutoff date of February 1, 1998. PACS are now operating in Africa and South America. Limiting this survey only to systems in actual daily clinical operation on a certain date was essential to defining the 2 survey periods.

This survey included PACS of all types and sizes. The earlier 2 surveys looked only at socalled "large PACS." The criteria used in 1993 and 1995 for such systems included (1) 3 or more digital modality types, (2) daily clinical operation, (3) terminals in and outside of radiology and a minimum of 20,000 annual exams on the PACS. What a difference between 1993 and 1998! Those then difficult-to-meet criteria now seem simple. Using those criteria there were 65 "large PACS" in 1998. In 1993 there were 13, and in 1995 there were 23. We believe the 1993 and 1995 counts were complete. The number of "large PACS" is known to be undercounted in 1998.

### **Opinions of PACS Users**

Perhaps the most startling single finding in the survey was almost unanimous (97%) willingness of the owners to recommend PACS to others. This was even true for those whose PACS had not met their expectations or was not viewed as cost effective. With many fewer responses all were willing to recommend PACS in 2000.

Another impressive response in 1998 was the 65% of the users who declared their PACS to be cost effective. The problem of properly attributing soft benefits in patient care, length of inpatient stays, benefits to clinicians and other factors to PACS are well known and vexing. This result is impressive particularly because the respondents are experienced users, anonymous, and not requesting a new system! In 2000 the 67% vote for cost-effective systems was unchanged.

In 1998 81% of the users reported that their PACS had met their expectations. A smaller group of respondents were similarly positive in 2000.

Satisfaction in the 2000 survey with the original vendor was given as satisfied or very satisfied in 67%. An additional 30% had mixed feelings. Eighty-nine percent of the facilities continued to use their original vendor.

The trend to expand the PACS between 1998 and 2000 was unmistakable with 89% reporting some expansion. The survey did not ask the system install dates, but from the high response rate, it would appear that both older systems as well as more recently installed systems underwent expansion. Many factors probably contributed, including more DICOM systems, decreased equipment costs, workflow improvements, and increased deployment of CR and DR units.

The use of both CR and DR was much changed from 1998 to 2000. There was a spectacular increase to 81% of facilities with greater than 50% of their plain radiographs on the PACS. Forty-five percent of these facilities had more than 90%. Of course, adding the numerous (and data intense) higher-resolution radiographic studies increased the percentage of the total departmental examinations handled by the PACS. The 24% of the facilities in 1998 with more than 80% of all departmental studies jumped to 56% on the PACS in 2000.

Furnishing images to locations outside of the

BAUMAN AND GELL

radiology department was well established in 1998. There were 14 systems that reported more than 100 display stations outside of radiology, 2 in Asia, 4 in Europe, and 8 in North America. The numbers ranged up to 7,000 stations, with others at 250, 400, 500, 700, and 700. These were mainly, but not all, academic centers. They also were enterprisetype PACS. Most of them are early users of Intranets to connect to personal computers (PCs) throughout the hospitals, clinics, and offices of their enterprises.

### **Operations of the PACS**

The 1998 systems have a broad range of included modality types. Systems with 6, 7, or all 8 modality types comprise 45% of the total. Systems with 5 modality types add another 21%. The percentage of each modality type on PACS with various numbers of modality types is in Table 8.

Taking all PACS into account the most commonly found modality type is CT at 83%. Although all of the PACS with 4 or more modality types include CT, it is surprising only 18% of 1 modality-type PACS had CT (38% of PACS with 2 types of modalities). One might expect MR to be close behind CT, but instead, there are 3 modality types grouped in a second tier. CR is next at 71%, then MR at 70%, and ultrasound at 66%. A third tier includes DF at 50%, and DA and NM at 43% each. NM has used computers for some time, so there might be problems with interfacing existing systems with a PACS. Another surprise was to find 5 hospitals reporting 100% of mammograms on their PACS. Three facilities reported soft copy reading of 20%, 100%, and 100% of their mammograms on the PACS. The first 2 are in Europe, and the latter is in Asia. The Asian facility also reported handling all of their mammograms filmlessly. No attempt was made to verify or question these reports.

The number of facilities using soft copy reading and the number of modality types so read in 1998 were both higher than expected. Thirty-one of facilities were reading either 5, 6, or 7 modality types from soft copy. Three modality types were read by soft copy in 50% or more of all reporting facilities: ultrasound at 58%, CR at 51%, and CT at 50%. MR was at 39%, and DA, DF, and NM all were in the low 30s.

The last surprise is that 73 facilities were already doing some filmless work in 1998. It is also im-

portant to realize that 73 is less than half of the PACS identified. The problem therein is that there are no data on whether the facilities that did not report explicitly on filmless modality types are doing any filmless work. Note that 22 (90%) of the reporting PACS were either "largely," "almost," or "completely filmless" by the criteria defined in the Methods section. In considering all filmless modality types on all of the reporting PACS, the most common filmless modality type was easily ultra-

1. Bauman RA: Worldwide experience with large PACS systems, in Proceedings of the S/CAR94 Computer Applications to Assist Radiology Conference. Winston-Salem, NC, Symposia Foundation, Carlsbad, CA, 1994

2. Bauman RA, Gell G, Dwyer SJ III: Large picture archiving and communication systems of the world—Part 1. J Digit Imaging 9:99-103, 1996 sound at 64%. Next came CR at 44% and CT at 41%. DF at 33% and MR at 30% were followed by DA at 25% and NM at 23%. A recent survey of several "filmless" departments is of interest.<sup>4</sup>

# ACKNOWLEDGMENT

The authors thank Joan-Marie Segota and Gabriele Bierbauer Kroell for their very significant contribution to the survey and database work. The authors also thank John Van Den Brink of the Technology Marketing Group for the listing of hospitals and some outpatient facilities in the United States.

### REFERENCES

3. Bauman RA, Gell G, Dwyer SJ III: Large picture archiving and communication systems of the world—Part 2. J Digit Imaging 9:172-177, 1996

4. Siegel E, Reiner B, Abiri M, et al: The filmless radiology reading room: A survey of established picture archiving and communication system sites. J Digit Imaging 13:22-23, 2000 (2 Suppl 1)