

## Large Picture Archiving and Communication Systems of the World—Part 1

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This is the report of a worldwide survey of 82 institutions done to identify large scale picture archiving and communication systems (PACS) in clinical operation in 1995. This survey found a continuing strong trend toward the creation and operation of large PACS. In the 15 months since the first such survey, the number of clinical large PACS went from 13 to 23, almost a doubling in that short interval. New systems were added in Asia, Europe, and North America. A strong move to primary interpretation from soft copy was identified, and filmless radiology has become a reality. Copyright © 1996 by W.B. Saunders Company

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

**I**N 1992 after more than a decade of discussion and expectations, there was a sense that clinical large picture archiving and communication systems (PACS) were next to nonexistent. A survey done on systems in place as of November 1, 1993<sup>1</sup> shattered that perception, as 13 hospitals were identified with large PACS in clinical operation. Has there been continuing growth in this type of system? This report seeks to identify new systems and changes that have happened during the next 15-month interval.

A very useful definition of a PACS was given by Dr Christian E. C. Greinacher, to wit, that a PACS consists of at least one or multiple imaging modalities (acquisition devices), a communication network, an intermediate and/or long-term storage device, and an image review and/or postprocessing workstation.

Consensus on what comprises a Large PACS is much more difficult. For the purpose of this study a Large PACS was required to meet three criteria: daily clinical operation, three or more modalities on the PACS, and terminals inside and outside of radiology. These criteria were also used in the 1993 survey. In addition, the

PACS must handle a minimum of 20,000 exams annually.

### MATERIALS AND METHODS

To identify possible PACS sites a screening questionnaire was sent by facsimile and/or mail to 88 United States institutions who were not known to have a PACS but who did have heavy computed tomography (CT) and/or magnetic resonance imaging (MR) caseloads. They were asked to indicate if they operated a mini-PACS, PACS, Teleradiology, Telemedicine, and/or a network connecting at least two digital acquisition devices and at least one extra console, and if so, whether the equipment involved had been furnished by only one vendor or by multiple vendors. Two respondents in this group reported having a PAC System.

The full survey group institutions were likely to have a significant PACS effort. They were identified through discussions with vendors, colleagues, and from personal knowledge of the authors. A two-page survey form was sent by facsimile and/or mail to 82 institutions worldwide.

Respondents were asked to characterize their institution as to bed-size and geographical dispersion. Communication systems in place as of February 1, 1995, were to be identified as none, mini-PACS only, PACS, PACS & Teleradiology, Teleradiology and/or Telemedicine. The vendor was asked to provide further information if a system was present.

Other queries included the number and distribution of PACS workstations, information on the type, protocol and speed of network transmission, and on the size and presence of various archive media.

The number of exams done annually was requested by modality for the entire department, as was the number of those exams sent to the PACS system by means of DICOM interfaces, other digital interfaces, analog interfaces or via digitizers. Also requested was the number of devices and the nature of the interfaces for each modality interfaced to the PACS and the mean number of images per exam by

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modality. The portion of exams by modality primarily interpreted from soft copy was also queried.

The modalities specified were computed radiography (CR), CT, digital angiography (DA), digital fluoroscopy (DF), MR, nuclear medicine (NM), and ultrasound (US).

The number of months of exams available by modality within 90 seconds of a request on a workstation was also asked, along with information on on-line and off-line availability of images and planned maximum image archive length. The last query by modality was the year of first clinical operation on the PACS for that modality.

Information was also requested for compression ratios used before interpretation and for archiving purposes. Lastly, the presence and nature of interfaces to a radiology system (RIS) and/or a hospital information system (HIS) was requested.

A follow-up form was sent to nonrespondents, which permitted a response of "no medium or large PACS in daily clinical operation."

**RESULTS**

*Screening questionnaire results.* Forty-four responses (50%) were received from the 88 institutions screened who were heavy CT and/or MR users but who were not thought to have a PACS. Table 1 presents the systems reported and the use of teleradiology by the 44 responding hospitals. The 7 institutions with only teleradiology reported single sites in 5 cases, 1 had 2 sites and 1 had 9 teleradiology sites. (A site with teleradiology was considered to have a single site if the question on the number of sites was unanswered.) The number of teleradiology sites for the 12 institutions with networked devices included six with single sites, 4 with 2 sites and 2 with 20 sites each. The 6 mini-PACS institutions had 5 single sites and 1 with 2 sites.

No further investigation of these hospitals was done except to include the two declared PACS in the survey group.

*PACS survey results.* Sixty-one responses (74%) were received from the survey group of

**Table 2. PACS Survey Group**

	No.	No PACS	Mini-PACS	PACS
Primary group surveys received	61	13	12	36
% Received		21.3%	19.7%	59.0%
No. reporting teleradiology use	29	2	5	22

82 institutions. Table 2 shows the systems reported by the 61 respondents on the two page survey form. Eighty-eight percent reported either a mini-PACS or PACS. Two of the institutions with no such system did do teleradiology to one site. Five of the 12 mini-PACS hospitals reported doing teleradiology also, each with a single site. The 22 institutions with PACS doing teleradiology reported 13 single sites, 5 had two sites and one each had 3, 6, 15, and 16 sites.

Thirty-seven of the hospitals with mini-PACS or PACS provided data on which modalities were in daily clinical use. The number of each of the seven modalities for which data was requested are shown under their two letter codes in Table 3 for systems with various numbers of active clinical modalities. This table shows which modalities are in use; as few as one up to all of the devices interfaced for a given modality qualify it for inclusion here. Digital cardiology is in clinical operation in one of the systems with five modalities.

Only 23 of the institutions with three or more modalities in daily clinical use met the criteria as Large PACS as presented in the Introduction. These are presented in Table 4. The year shown is the year in which three modalities were

**Table 3. Clinical Modalities**

	No. of Systems	Modalities						
		CR	CT	DA	DF	MR	NM	US
PACS with 1 modality only	6	4	1	0	0	0	1	0
PACS with 2 modalities	5	0	4	1	0	3	1	1
PACS with 3 modalities	10	7	9	2	1	8	2	1
PACS with 4 modalities	5	4	5	4	0	4	1	2
PACS with 5 modalities	7	6	7	4	3	5	4	5
PACS with 6 modalities	2	2	2	1	1	2	2	2
PACS with 7 modalities	2	2	2	2	2	2	2	2
Totals	37	25	30	14	7	24	13	13

**Table 1. Systems Reported by Hospitals Screened**

	No Teleradiology	Teleradiology	Totals
PACS	1	1	2
Mini-PACS	5	6	11
Multiple devices with independent console, single vendor	5	10	15
Multiple devices with independent console, multiple vendors	4	2	6
Teleradiology only		7	7
No system at present	3		3
Totals	18	26	44

**Table 4. Large PAC Systems**

1993		
1988	Yes	University Hospital Graz
1989	Yes	Hokkaido University Hospital
1989		The Credit Valley Hospital
1992	Yes	Danube Hospital—SMZ0
1992	Yes	Free University of Brussels, PRIMIS
1992	Yes	Madigan Army Medical Center
1992	Yes	UCLA Health Sciences Center
1992	Yes	University Hospital of Geneva
1992	Yes	University of Florida
1992	Yes	Wright Patterson AFB Medical Center
1993	Yes	Baltimore VA Medical Center
1993	Yes	Brooke Army Medical Center
1993	Yes	University of Pittsburgh
1993		Viborg County Hospital
1994		Brigham & Women's Hospital
1994		Conquest Hospital
1994		Houston VA Medical Center Hospital
1994		Osaka University Hospital
1994		Samsung Medical Center
1994		Toshiba Hospital
1994		Univ. of California San Francisco
1994		University of Virginia
1995		Hospital of the Univ. of Pennsylvania

**Table 6. PACS to Information System Interfaces**

Both HIS and RIS Interfaces	
Brooke Army Medical Center	Conquest Hospital
Danube Hospital—SMZ0	Free University of Brussels,
Hokkaido University Hospital	PRIMIS
Samsung Medical Center	Osaka University Hospital
UCLA Health Sciences Center	Toshiba Hospital
University Hospital of Geneva	Univ. of California San
University of Pittsburgh	Francisco
	University of Florida
	Viborg County Hospital
PACS-HIS Interfaces	
Baltimore VA Medical Center	Houston VA Medical Center
The Credit Valley Hospital	Hospital
	Wright Patterson AFB Medical
	Center
PACS-RIS Interfaces	
Brigham & Women's Hospital	Hospital of the Univ. of
Madigan Army Medical Center	Pennsylvania
	University Hospital Graz

first in routine clinical use. The second column identifies the 12 systems, which were also in operation as Large PACS in November of 1993.<sup>1</sup>

Many institutions reported more modalities interfaced to their PACS or mini-PACS than were in clinical operation. Table 5 shows these interfaces by modality for the 42 systems which provided data. The minimum number of devices for a modality was one, and the bottom line shows the largest number of such devices interfaced to a PACS by any of the hospitals (rather than the number of institutions with any interfaces for that modality as in the main part of the table.)

Twenty-two of the 23 Large PACS institutions reported operational interfaces between the PACS and either the HIS, the RIS or both as shown in Table 6.

The query on whether interpretation of some studies was done primarily from soft copy on the PACS rather than from radiographs elicited a positive response from 22 institutions in the survey group. They are listed by the amount of such primary interpretation done in Table 7. Seventeen of the 23 Large PACS group did some primary interpretation.

The institutions with Large PACS are listed by continent in Table 8.

The commercial vendors of the large PAC Systems are shown in Table 9.

Details of other technical responses will be reported in a subsequent publication.

**DISCUSSION**

Every effort was made to include all of the Large PACS in the world in the survey group, but the possibility of missing a site exists. There were 21 surveyed sites which did not respond; personal knowledge and indirect inquiries con-

**Table 5. Interfaces to PAC Systems by Modality**

	CR	CT	DA	DF	MR	NM	US	Other
Large PAC systems, N = 22	19	22	17	10	18	10	13	4
% of total	86%	100%	77%	45%	82%	45%	59%	18%
Other PAC systems, N = 20	11	13	6	2	11	5	6	0
% of total	55%	65%	30%	10%	55%	25%	30%	0%
All PAC systems, N = 42	30	35	23	12	29	15	19	4
% of total	71%	83%	55%	29%	69%	36%	45%	10%
Maximum no. of devices interfaced for each modality	12	9	4	4	10	10	16	1

**Table 7. Primary Interpretation on PACS**

All	
Baltimore VA Medical Center	Baltimore, MD
Danube Hospital—SMZ0	Vienna, Austria
Much	
Houston VA Medical Center Hospital	Houston, TX
Madigan Army Medical Center	Tacoma, WA
Toshiba Hospital	Tokyo, Japan
Viborg County Hospital	Viborg, Denmark
Some	
Brigham & Women's Hospital	Boston, MA
Brooke Army Medical Center	San Antonio, TX
Conquest Hospital	Hastings, UK
Free University of Brussels, PRIMIS	Brussels, Belgium
Hammersmith Hospital	London, UK
Hokkaido University Hospital	Sapporo, Japan
Hospital of the Univ. of Pennsylvania	Philadelphia, PA
Laboratoire Sim; Faculte de Medecine	Rennes, France
Nagoya Univ. School of Medicine	Nagoya, Japan
Samsung Medical Center	Seoul, Korea
Skejby Hospital	Aarhus, Denmark
The Credit Valley Hospital	Mississauga, Ontario
University Hospital Graz	Graz, Austria
University of Florida	Gainesville, FL
University of Virginia	Charlottesville, VA
W. Los Angeles VA Medical Center	Los Angeles, CA

cerning them have made it improbable that any of them and certainly not more than one or two of them could have an operational Large PACS at the time of the survey.

The use of PACS for clinical modalities (Table 3) contains some surprises. Among the mini-PACS with only one modality four out of the six were CR installations. Among the five mini-PACS with two modalities 60% operated both CT and MR. Indeed, the CT and MR combination was present in at least 71% of the hospitals with 3, 4, 5, 6, and 7 modalities on their PACS. CR was not used in the five institutions with two modalities, perhaps relating to the small sample size. However, in hospitals with three or more modalities the PACS included CR, CT, and MR in at least 70% of the systems. DA was the next most frequently added modality, followed by either NM or US; DF was usually added later. It should be noted that some of the systems with three or more modalities

did not qualify as Large PACS, and two of the Large PACS group did not furnish enough data to be included in Table 3.

The number of institutions with one or more acquisition devices of a particular modality interfaced to their PACS are shown in Table 5 for the 22 of 23 Large PACS who furnished detailed data and for 20 other systems. Comparison with the modality data shows that far more modalities have been interfaced than are in operational use. The last line in the Table shows the actual maximum number of devices interfaced for that modality by at least one institution.

The vital nature of data sharing between PACS and information systems (IS) was uniformly recognized. The only large PACS without an operational interface was actively implementing one. Others were improving their interfaces actively, too. Some of these systems were developed with the PACS integral to the

**Table 8. Location of Large PACS**

Asia	
Hokkaido University Hospital	Sapporo, Japan
Osaka University Hospital	Osaka, Japan
Samsung Medical Center	Seoul, Korea
Toshiba Hospital	Tokyo, Japan
Europe	
Conquest Hospital	Hastings, UK
Danube Hospital—SMZ0	Vienna, Austria
Free University of Brussels, PRIMIS	Brussels, Belgium
University Hospital Graz	Graz, Austria
University Hospital of Geneva	Geneva, Switzerland
Viborg County Hospital	Viborg, Denmark
North America	
Baltimore VA Medical Center	Baltimore, MD
Brigham & Women's Hospital	Boston, MA
Brooke Army Medical Center	San Antonio, TX
Hospital of the Univ. of Pennsylvania	Philadelphia, PA
Houston VA Medical Center Hospital	Houston, TX
Madigan Army Medical Center	Tacoma, WA
The Credit Valley Hospital	Mississauga, Ontario
UCLA Health Sciences Center	Los Angeles, CA
Univ. of California-San Francisco	San Francisco, CA
University of Florida	Gainesville, FL
University of Pittsburgh	Pittsburgh, PA
University of Virginia	Charlottesville, VA
Wright Patterson AFB Medical Center	Dayton, OH

**Table 9. Large PACS by Vendor**

Emed	
Houston VA Medical Center Hospital	University of Virginia
Internally Managed	
Free University of Brussels, PRIMIS	Hospital of the Univ. of Pennsylvania
UCLA Health Sciences Center	Univ. of California-San Francisco
University Hospital of Geneva	University of Pittsburgh
Kodak	
Brigham & Women's Hospital	University of Florida
Loral	
Baltimore VA Medical Center	Brooke Army Medical Center
Madigan Army Medical Center	Samsung Medical Center
Wright Patterson AFB Medical Center	
NEC	
Hokkaido University Hospital	Osaka University Hospital
Philips	
The Credit Valley Hospital	
Siemens	
Danube Hospital—SMZO	University Hospital Graz
Viborg County Hospital	
Simis	
Conquest Hospital	
Toshiba	
Toshiba Hospital	

IS. Because the systems had to have been ordered some time ago to be operational at the time of this survey, only a small number are standard digital imaging and communications and medicine (DICOM) based open systems.

One of the most surprising findings of this survey is the large number of hospitals doing at least some primary interpretation of studies

directly from the PACS. Seventeen of the 23 Large PACS group and 5 other hospitals reported that they were doing interpretation from monitor displays rather than from hard copy for at least one modality.

Another most interesting situation was not covered by a specific survey question. The authors understand that there are three hospitals that are now doing completely filmless operation except for mammography. These are the Baltimore Veterans Administration Medical Center, the Danube Hospital (SMZO), and the Viborg County Hospital.

There are now four Large PACS in Asia, six in Europe and thirteen in North America. Five of the 12 in the United States are federally funded institutions.

These Large PACS have been installed by eight different commercial vendors. Six institutions have managed the development of their Large PACS in-house: the Free University of Brussels (PRIMIS), the Hospital of the University of Pennsylvania, the UCLA Health Sciences Center, the University Hospital of Geneva, the University of California-San Francisco, and the University of Pittsburgh.

Throughout 1995 and 1996 there has been increasing awareness of the value of these systems in managing and operating competitive radiology practices. The trend toward open systems has become almost a necessity, and the wider healthcare networks that go beyond hospital boundaries pose new challenges. PAC Modules operating within such networks may be sold in addition to complete PACS, as found in the survey. A third survey is planned to capture additions and changes after another 15-month period. Please send the authors news of any new institutions that should be included.

## REFERENCES

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