The Successful Usage of the DICOM Images Exchange System (ePACS) in the Czech Republic

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Abstract

Background The picture archiving and communication system (PACS) has already replaced classic hard copy film technology. With new functions of PACS under consideration, attention turns to the sharing of medical images between different institutions. The Czech Republic is one of the few countries using a nation-wide medical images exchange system known as ePACS. It is based on dedicated hardware and one central router, although theoretical models tend to prefer cloud-based sharing.

Objective Despite its simple design and lack of advanced features, this system has successively evolved into a widely used tool. The aim of this article is to offer an overview of its use and functions and to show that even a simple system can be widely used.

Methods Using data from the producer of ePACS (the ICZ company) and from other sources, the system was described and data about its performance have been obtained.

Results Every acute-care hospital (140) and about a quarter of outpatient facilities (105) in the Czech Republic are now equipped with ePACS and are therefore able to share medical images. The number of studies transmitted rises every year, from 12,000 in 2008 to more than 640,000 in 2018, which is approximately 4% of all studies produced. The system was primarily designed and is used to share images between acute-care hospitals but a very special usage has also evolved, as it is employed in a teleradiology service with private enterprises too.

Conclusion ePACS is expanding in the Czech Republic despite having only limited functions and despite its principle that simply copies a classic workflow when sending studies on Compact Discs. Although other systems for image sharing might be more advanced, ePACS brings to the Czech health care system the capability to exchange medical images on a national level.

Keywords

- DICOM
- PACS
- information systems
- cloud computing
- radiology information systems

Background and Significance

Picture Archiving and Communication System

The picture archiving and communication system (PACS) has replaced classic hard copy film technology with a filmless environment, starting in the United States,[1] spreading to Europe,[2] and reaching the developing countries.[3] Usage of PACS has a positive effect on hospital efficiency, patient experience, and outcome scores.[4] Evidence suggests that the change of workflow associated with the use of PACS has resulted in a 20 to 60% increase in the efficiency of technologists, more than 50% for clerical staff, and more than 40% for radiologists.[5] Nevertheless, the radiologists' workflow change and reduced contact with clinicians might sometimes be perceived as a disadvantage.[6] New PACS functions, such as integration with the rest of the hospital information system, computer-aided detection applications, and postprocessing of multidimensional data are under consideration and introduction.[7]

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Acquisition of Images from Other Institutions

Attention is now turning to the acquisition of images from other institutions. This can be achieved by importing images using compact discs (CD) or internet transfer. It has been proved that these methods reduce repeat imaging utilization,[8,9] cost, and radiation exposure.[10] However, CD importing does not always work[11] and, above all, its usage in emergency situations is only limited. Sharing of medical images between institutions without the necessity of physical media or dedicated peer-to-peer connections is therefore increasingly seen more and more as a necessary extension of PACS.[12,13] This view is already reflected in British national strategy,[14] although The Health Information Technology for the Economic and Clinical Health Act (HITECH) in the United States, even in its meaningful use for EHR stage 3, does not require sharing of medical images.[15]

Multiple connections are usually considered for the replacement of existing stand-alone PACS in different institutions, either using a cloud PACS[16,17] or even cloud PACS as a service,[18] as opposed to peer-to-peer connections with dedicated virtual private networks (VPN) between existing PACS. Image exchange between existing PACS even from different vendors can be facilitated using the Healthcare Enterprise Cross Enterprise XDS-I Sharing Profile.[19,20] Such existing PACS can be connected using DICOM relay over the cloud[21] and can even provide individualized patient-controlled access to the stored images.[22] A much simpler approach may be seen in German standards for teleradiology, where DICOM e-mail is suggested as a preferred way of image sharing.[23]

Although there is ample description of theoretical models to facilitate the medical images exchange system (MIES) in scientific literature,[24,25] the solutions implemented are discussed much less frequently. For example, the Baltic eHealth project and R-Bay project were conducted as pilot studies in Europe in teleradiology about 10 years ago.[26] In Japan, a cloud-based patient identifier cross-reference manager is used to connect four different hospitals in the Oshidori-Net2 system.[27] In the United States, Harborview Medical Center can receive images from 109 referring community hospitals using connections via VPN and CD import.[10] In Canada, a unique Health Infoway solution called DI-r (digital imaging repository) is based on the XDS-I Sharing Profile. DI-r is a centralized PACS repository to which any connected institution has access. It is not a national project, as it exists in 19 regional implementations,[28] meaning that only institutions from that region have access to it. In Ireland, a national PACS and radiology information system known as the National Integrated Medical Imaging System (NIMIS) is used with images stored both locally and at a central data repository. Users can view and order images from their current hospital site and via PACS have access to existing imaging on all the other sites.[29]

Background of the Czech Republic

The Czech Republic is a Central European country with a population of 10.65 million in 2019. Every inhabitant is compulsorily insured by one of seven health insurance companies which then act as payers for health care. The total health care system consumes approximately 7.1% of the Czech gross domestic product per annum.

Outpatient care is provided by general practitioners and outpatient specialists, who might work individually or in association with larger units. Inpatient care is provided by the following three types of facilities: local hospitals, regional hospitals, and specialized university and county hospitals. The latter provide the most advanced type of care and patients are routinely transferred there from the less advanced types of facilities.

The Czech health care system uses a unique patient identifier, into which everyone is slotted at birth. In addition, anyone with a health insurance in the Czech Republic is also received into the identification system. Searching in the PACS for an image is performed using this means of identification.

An electronic prescription system exists in the Czech Republic, but there is no other system for medical data sharing. Reports of any kind and referrals are thus transferred only in paper form. Transferring a patient from one institution to another still mainly involves the use of a telephone.

Objectives

MIES and thus the ability to exchange medical images between different health care institutions improves the quality of health care by reducing the necessity to repeat the imaging, by enabling telemedicine and by facilitating continuity of care. Even so, only a limited number of countries possess a nation-wide system that has this capability. One of them is the Czech Republic, where a pilot study of MIES, later to be named ePACS, was launched in 2008.

Despite its simple design and lack of advanced features, this system has successively evolved into a widely used tool. The aim of this article is to offer an overview of its use and functions and to show that even a simple system can be widely used as a national MIES.

Methods

Information about past history, technical description, and current functions was obtained from a dedicated web page, available only in Czech[30] and from nonstructured interviews with representatives of the supplier of ePACS, the joint-stock company ICZ, in the Czech Republic. A series of three interviews was conducted, focusing on the above-mentioned topics. Both interviewees serve as managers responsible for medical systems in ICZ, among them ePACS.

The information obtained is presented in this article, including the rationale to develop the system, its gradual development, and the principles and functionalities of ePACS.

An actual list of all connected health care facilities was obtained from a dedicated webpage. Representatives of ICZ also provided data to ascertain usage of ePACS. Monthly summaries of institutions connected to ePACS, as well as annual summaries of the DICOM studies transmitted, were provided. ICZ also provided anonymized data from the top 10 institutions that sent and received most studies via ePACS in 2018.

No Institutional Review Board approval was needed for this research, as no individual data, either on a patient or an institution, were handed over.

Results

Development, Principles, and Functionalities of ePACS

The project started as a private activity of ICZ, the supplier of different IT technologies, among them the PACS system now sold as AMIS*PACS. The goal was to provide an alternative to transferring DICOM images on CD. Prior to the development of ePACS, CDs were the sole method of transferring DICOM images. In fact, CDs containing DICOM images were transported by ambulance cars in the setting of emergency consultations and patients would carry CDs to their outpatient providers to ensure continuity of care. The goal was achieved by offering a low-cost solution to enable the sending of DICOM studies from one stand-alone PACS to another, irrespective of the vendor of the original PACS. With backing from the Czech Ministry of Health three hospitals in Prague were initially connected in 2008.

The ePACS has one central router (CR), located in the General Teaching Hospital in Prague. Every connected institution then has a communication node (CN), which is linked to the CR via a VPN tunnel, where DICOM is used as the communication protocol. A DICOM study located in the PACS of one institution can be sent to any connected institution. DICOM packets travel via the originating CN to the CR, where they are routed to the receiving CN. IHE XDS-I was not chosen, as it was deemed more complicated to implement. The chosen solution enabled a seamless integration, as the study from the receiving CN is pushed in the PACS of the receiver. Such integration would not be possible with DICOM e-mail.

The basic CN, named AMIS*PACS CommunicationNode, simply provided the bidirectional connection to the CR. Later, an upgraded version of CN, named AMIS*PACS YellowBox, was introduced, this version includes a small PACS archive, and is thus suitable for small institutions without an existing PACS archive. Alternatively, an institution with its own PACS can use YellowBox to receive studies from other institutions and, therefore, separate them from studies created in their own institution.

After the pilot study of 2008 to 2010, the next phase continued in 2010 to 2012. The basic principle was retained and further CNs were introduced as more institutions were connected. This expansion was financed from low connection fees (~1,000 USD per institution per annum) and the General Teaching Hospital received a grant from the Ministry of Health to manage the CR. The system has been fully operational from 2013 onwards, with even more institutions being connected. ICZ did not arrange any special marketing to promote ePACS, since institutions usually joined the project after recommendations from another user.

A new option was also introduced for physicians and institutions which do not produce medical images and do not need their own PACS solution. Dedicated storage with free of charge and 2 GB capacity can be provided where the studies are stored until the user downloads them.

From a technical point of view, CN is just another DICOM modality, so it can be connected to any existing PACS system. CN periodically receives a current list of connected institutions from CR. Sending a study is then possible from any PACS viewer used in the originating institution, it just needs to be selected, with a definite destination chosen. The copy of the study is then sent via CN to CR and thereafter to the destination.

CR, as the name implies, works only as a router. The data are routed from one VPN tunnel to another, and it is only the transfer information that is stored in the CR in the long term, not the data itself. The General Teaching Hospital needs a CN of its own to connect to ePACS.

Anyone having access to the original DICOM study and to the originating PACS can initiate the transfer via ePACS. Only one study of a single patient can be sent at any one time. For security and technical reasons, it is not possible to send multiple studies or studies from different patients all at the same time.

As there is no information system for ePACS management and as there is no general index of existing medical images in different institutions in the Czech Republic, nobody outside the originating institution has the means to do the transfer or even ascertain whether a study exists. In the receiving institution, anyone having access to their PACS can view the study received.

Access control and security policy are thus fully responsibility of the individual institutions; users from these institutions are not registered with ePACS and do not need any credentials. The only difference is in the users of storage, valid personal electronic certificates are needed for these users to authenticate themselves in the storage system.

The active role always remains with the sending institution, and this typically defines the way of using ePACS. Moreover, ePACS does not provide any information if a study exists of a particular patient in some other institution. If a study is requested on the receiving side, it is usually made by telephone, although some of the PACS viewers enable the users to send the request to the originating institution electronically. Usually only DICOM studies without image reports are sent via ePACS, since the system does not connect individual radiology information systems in the Czech Republic in which the image reports are commonly stored.

The principle of ePACS is illustrated in ►Fig. 1.

Usage of ePACS

ICZ provided monthly summaries of institutions connected to ePACS. Results related to December each year are listed in ►Table 1.

There is a current list of all institutions connected to ePACS.[31] By manually reviewing each entry, several duplicates were identified, and then the institutions were divided according to location (Czech Republic, Slovak Republic, or Great Britain) and to type (inpatient facilities: hospitals and sanatoriums; outpatient facilities: outpatient clinics and private radiology centers; individual physician facility: an outpatient facility with just one physician; and scientific facility: a scientific institution without any healthcare function). The results are listed in ►Table 2.

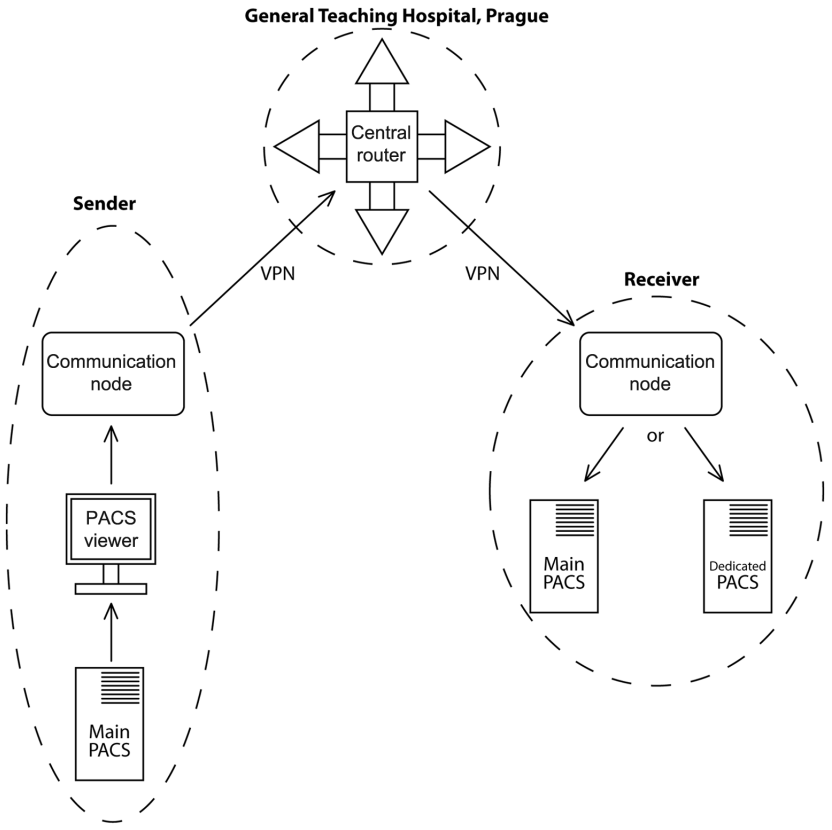

Fig. 1 The principle of ePACS. ePACS, exchange system picture archiving and communication system; VPN, virtual private networks.

Table 1 Number of institutions connected to ePACS at the end of each year

2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
65	112	143	176	210	228	265	288	315	346	384

Abbreviation: ePACS, exchange system picture archiving and communication system.

Table 2 Number of healthcare facilities connected to ePACS in 2019—according to type and location

Facility	*n*
Inpatient (Czech Republic)	140
Inpatient (Slovak Republic)	6
Inpatient (Great Britain)	1
Outpatient (Czech Republic)	105
Outpatient (Slovak Republic)	1
Single Physician (Czech Republic)	122
Scientific (Czech Republic)	2

Abbreviation: ePACS, exchange system picture archiving and communication system.

In ►Table 3 an annual summary of DICOM studies transmitted using ePACS is given, the data have been provided by ICZ.

In ►Tables 4 and 5, the data were made anonymous by ICZ and therefore only the type of institution is revealed, and not its actual name. In ►Table 4, the top 10 most frequent senders for 2018 are listed, and in ►Table 5, the top 10 most frequent receivers for that year are listed. For each figure, a percentage relation to a total sum of ePACS studies transmitted in 2018 (►Table 3) is provided.

Discussion

ePACS successfully achieved its goal to provide an electronic alternative to CD transfer of DICOM data. Instead of CDs

Table 3 Number of studies transmitted via ePACS (total per year)

2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
12,732	48,376	102,301	160,132	226,570	323,399	370,935	422,144	485,172	594,227	641,239

Abbreviation: ePACS, exchange system picture archiving and communication system.

Table 4 Number of studies sent in 2018—top 10 institutions, anonymized

Study	*n*	(%)
County hospital	16,961	2.65
Private radiology	13,835	2.16
Hospital in Prague	13,572	2.12
District hospital	13,236	2.06
Private radiology	12,603	1.97
University hospital	11,616	1.81
University hospital	11,320	1.77
Private radiology	10,445	1.63
University hospital	9,887	1.54
University hospital	9,787	1.53

Table 5 Number of studies received in 2018—top 10 institutions, anonymized

Study	*n*	(%)
Private radiology	84,671	13.20
University hospital	43,056	6.71
University hospital	21,298	3.32
Hospital in Prague	19,765	3.08
University hospital	18,372	2.87
University hospital	17,254	2.69
Hospital in Prague	16,837	2.63
County hospital	16,648	2.60
University hospital	16,226	2.53
University hospital	15,932	2.48

delivered by ambulance or via the patient, both of which methods can take hours or days, medical images are guaranteed to arrive in a few minutes. However, this primary design leads to limited usage, as it is not possible to ascertain whether a patient study exists in some other institution in the Czech Republic, and only the sender can initiate the transfer. With this type of design, ePACS can hardly be used to gather data in emergency situations, as it would mean contacting a multiplicity of hospitals. In such cases, new imaging is performed instead. ePACS decreases the number of studies duplicated, but it cannot eliminate duplicate imaging altogether.

ePACS is, from a technical and functional point of view, seamlessly integrated in the PACS of any institution, since CN works as a PACS modality and the sending of a study is initiated by choosing the destination from an updated list of connected institutions. Integration is seen as a decisive function when using electronic medical systems.[32]

Access rights to ePACS in some quarters might be seen as a source of controversy. Using access rights to the institutional PACS to enter a national system might be a legal issue in some countries. In the case of ePACS, though, this solution has not been disputed by authorities so far. Moreover, it simplifies the whole system and complies with a single sign-on principle that has proved beneficial in other applications.[33]

As ►Table 1 clearly demonstrates, the number of ePACS users has been rising steadily over time. More insight into the usage of ePACS can be acquired from ►Table 2 where users are divided into specific groups and locations. Evidently, ePACS should be perceived as a system geographically limited to the Czech Republic. According to the ICZ, a few connected Slovak users employ ePACS, though only marginally, and the only inpatient facility in Great Britain, Addenbrooke's Hospital, and University of Cambridge, does not participate in its routine operation at all.

This geographical limitation may well be due to the origin of the system; it was produced by a Czech company and supported by a Czech ministry. It seems there never was any ambition to produce an international project, apparently this technological solution is developed on a scale suitable simply for one country and the legal aspects would also otherwise be challenging. According to data from the Institute of Health Information and Statistics of the Czech Republic,[34] there were 156 acute-care hospitals, 389 outpatient facilities, and 21,975 individual physician facilities in the Czech Republic in 2017 (more recent data are not available at the moment). Comparing data from ►Table 2, this would mean that 89% of acute-care hospitals, 27% of outpatient facilities and 0.6% of individual physician facilities are connected via the ePACS system.

However, the stated number of 156 acute-care hospitals might not be correct. The smallest facilities tend to reduce their health care year-by-year basis and also close the inpatient services or operation as whole. Official statistics might be slow in observing this process. To clarify this, the list of all inpatient facilities connected to ePACS in the Czech Republic was reviewed manually, leading to the conclusion that every acute-care hospital in this country is nowadays connected and can use ePACS for image exchange.

The summary of facilities connected to ePACS (377 at the beginning of 2019 according to ►Table 2) does not equate with the number of users provided by ICZ (384 at the end of 2018; ►Table 1). This disparity can be attributed to a slight mismatch, as a few institutions are duplicated in the list. Also, three testing entities were identified on the list and these, too, have been removed. Thus, 377 users are seen as the actual figure as from the beginning of 2019. ICZ does not regard the duplications and disparities worth addressing as long as every user connected to the system can be reached by any other user.

The number of studies transmitted corroborates the theory that usage of ePACS is still rising, as more studies are transmitted every year. Since only the total sum of users exists (there is no older data which would enable the division of existing users into type and location), we may speculate as to whether this rise is caused by more users entering the system or by present users increasingly implementing the system. Extrapolating available data from 2016,[35] there were some 15.7 million studies produced in the Czech Republic in 2018. The studies transmitted in 2018, therefore amount to approximately 4% of all studies produced in that year.

Qualitative data would be useful to better assess ePACS, but due to the relative simplicity of the system (no managing

information system, CR used only to transfer and not to store DICOM studies), this data are not monitored, so it is not possible to acquire the number of different types of studies transferred. Neither is the purpose of the transfer entered in the system.

Nevertheless, more insight into ePACS usage can be obtained by reviewing those institutions which have sent and received the most studies. Of material sent, there are seven hospitals, four of them University hospitals and three private radiology enterprises, which produce images ordered by other physicians and institutions. Of the studies received, there are nine hospitals, but the top receiver is a private radiology enterprise that specializes in descriptions of images produced by other institutions.

The usage of ePACS has unfolded into three main categories. One is the sharing of medical images between acute-care hospitals. This usually happens when the patient is transferred from one hospital to another. Moreover, this sharing can be used, and from the author's clinical experience actually is used for consultation purposes to decide whether to transfer the patient at all. Given the possibility of using ePACS in any acute-care hospital in the Czech Republic, it can now safely be stated that there is no longer any need to send image data using CDs, when the patient is transferred or consulted. There is no official study on this topic, but unofficially Czech radiologists claim that they have rarely seen CDs used for this purpose in recent years.

The second category is the sharing of medical images between an acute-care hospital and an outpatient or individual physician facility to enable continuity of care. Judging by the number of facilities connected (those of all acute-care hospitals, just one quarter of outpatient facilities and less than 1% of individual physicians), it is obvious this sharing is much less common than sharing between acute-care hospitals.

The third category, given the primary intentions of ICZ, is somewhat surprising. ePACS is now widely used for teleradiology. The private radiology enterprises figure in both top institutions sending and receiving the studies. From this can be concluded that ePACS is used for both scenarios: to deliver the medical images ordered from the private enterprises which produced them and also to deliver medical images to an enterprise to have them described. With the latter in mind, ePACS enables the smaller institutions to retain and even increase medical images production without needing to have their own dedicated radiologist. ePACS is therefore providing better health care without burdening institutions with rising staff costs. According to ICZ, ePACS has not been intended for teleradiology. This usage has evolved throughout; ICZ has never limited types of institutions connected as long as they meet the criteria of a health care institution.

Although ePACS has only limited functions, as well as the above-mentioned limitations, it can be seen that the system has evolved into widely-used MIES in the Czech health service and Czech users now perceive ePACS as a valuable service, medical reports are still sent on paper in the Czech Republic but medical imaging can and is being sent via this system. The simplicity of ePACS and its very modest aims might have contributed to this achievement.

As already discussed in the introductory section, there is no world standardization on MIES. NIMIS and DI-r are robust systems with a patient master index, so imaging produced in the country (as with NIMIS) or at least in the region (as with DI-r) is easily available. ePACS is in comparison a nimble system, which simply replaced sharing medical imaging on CD with an electronic solution. Some other European countries might be using their national Electronic Health Record as a substitute for MIES but, in fact, most of them cannot share medical data nationally. Introducing a robust system, such as NIMIS, may be complicated by security and financial obstacles and by technical issues when connecting diverse PACS in different institutions.

In accordance with contemporary European Union (EU) strategies on sharing of medical data, it would be beneficial to introduce a national standard for the sharing of medical images. Neither ePACS nor NIMIS would be suitable for this role, as the latter is built on the scale of one country. Such a system would need a master patient index but the data would have to be stored in smaller repositories.

Conclusion

The data show that there is a functional and still expanding MIES in the Czech Republic, known as ePACS. It connects all acute-care hospitals and one quarter of outpatient facilities, but its coverage of individual physician facilities is almost nonexistent. It is widely used when sharing images between acute-care hospitals but much less used for sharing images for continuity of care. It is also used for teleradiology. ePACS usability is nevertheless limited to the Czech Republic, since there are only a very few installations abroad.

Although the functions of ePACS are limited, Czech health care is, thanks to its existence, one of a selected few countries in which is it possible to share medical images using just one system throughout the country. If not the actual design, then at least the very existence of ePACS presents a positive example to other health care systems.

Further studies in this field should go on to describe MIES in other countries. An international comparison of different MIES would also be beneficial, though at present no detailed information about them is available in scientific literature.

Clinical Relevance Statement

Although the PACS is a powerful clinical tool, its usage in most countries is still limited to local usage. The Czech Republic is one of the few countries using a nation-wide medical images exchange system. This system (ePACS) therefore presents a positive example to other health care systems.

Multiple Choice Questions

1. The picture archiving and communication system (PACS) is:

   a. A widely-used system for laboratory results exchange.
   b. An experimental system for storing medical images.
   c. A widely-used system for storing medical images.

d. A concept for storing medical images, though still not implemented.

Correct Answer: The correct answer is option c. "Widely-used" according to the PACS definition: that is, most, if not all, contemporary imaging systems are connected to PACS systems

2. Nation-wide medical images exchange systems

a. Are used in almost all EU countries.
b. None exist, as medical images cannot be exchanged between different institutions.
c. Are at present being widely deployed across the world.
d. Exist only in a few countries, though local images exchange systems are more common.

Correct Answer: The correct answer is option d. Only a few countries (such as the Czech Republic, Ireland, and Canada) have a nation-wide medical images exchange system in routine use.

Protection of Human and Animal Subjects

Human and/or animal subjects were not included in the project.

Conflict of Interest

None declared.

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