Research article

Centralized expert HRCT Reading in suspected idiopathic pulmonary fibrosis: Experience from an Eurasian teleradiology program

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ABSTRACT

Purpose: To share experience from a large, ongoing expert reading teleradiology program in Europe and Asia aiming at supporting referring centers to interpret high-resolution computed tomography (HRCT) with respect to presence of Usual Interstitial Pneumonia (UIP)-pattern in patients with suspected Idiopathic Pulmonary Fibrosis (IPF).
Method: We analyzed data from 01/2014 to 05/2019, including HRCTs from 239 medical centers in 12 European and Asian countries that were transmitted to our Picture Archiving and Communication System (PACS) via a secured internet connection. Structured reports were generated in consensus by a radiologist with over 20 years of experience in thoracic imaging and a pulmonologist with specific expertise in interstitial lung disease according to current guidelines on IPF. Reports were sent to referring physicians. We evaluated patient characteristics, technical issues, report turnaround times and frequency of diagnoses. We also conducted a survey to collect feedback from referring physicians.
Results: HRCT image data from 703 patients were transmitted (53.5% male). Mean age was 63.7 years (SD:17). In 35.1% of all cases diagnosis was "UIP"/"Typical UIP". The mean report turnaround time was 1.7 days (SD:2.9). Data transmission errors occurred in 7.1%. Overall satisfaction rate among referring physicians was high (8.4 out of 10; SD:3.2).
Conclusions: This Eurasian teleradiology program demonstrates the feasibility of cross-border teleradiology for the provision of state-of-the-art reporting despite heterogeneity of referring medical centers and challenges like data transmission errors and language barriers. We also point out important factors for success like the usage of structured reporting templates.

1. Introduction

Idiopathic pulmonary fibrosis (IPF) is a chronic, progressive fibrosing interstitial pneumonia characterized by an irreversible loss of lung function with unknown aetiology. It accounts for 55% of idiopathic interstitial pneumonias (IIPs) [1] and is the most lethal subtype with an estimated median survival of 3–5 years [2]. Its incidence increases steadily with age and most patients are older than 50 years [3,4]. There is large regional variation in incidence with a range of 3–9 per 100,000/year in North America and Europe [5]. Before the

diagnosis of IPF is made, other causes of interstitial lung disease (ILD) such as hypersensitivity pneumonitis, asbestosis or ILD associated with rheumatologic disorders must be excluded [6]. After exclusion of such causes, interpretation of HRCT pattern plays a key role in the diagnostic process, since identification of a Usual Interstitial Pneumonia (UIP) pattern may result in the diagnosis of IPF without further histopathological confirmation. Features of UIP pattern are honeycombing, reticulation and traction bronchiectasis/bronchiolectasis with a basal and subpleural predominance [6,7]. Fig. 1 shows an example HRCT of a patient with UIP pattern. If the HRCT pattern is inconclusive, lung
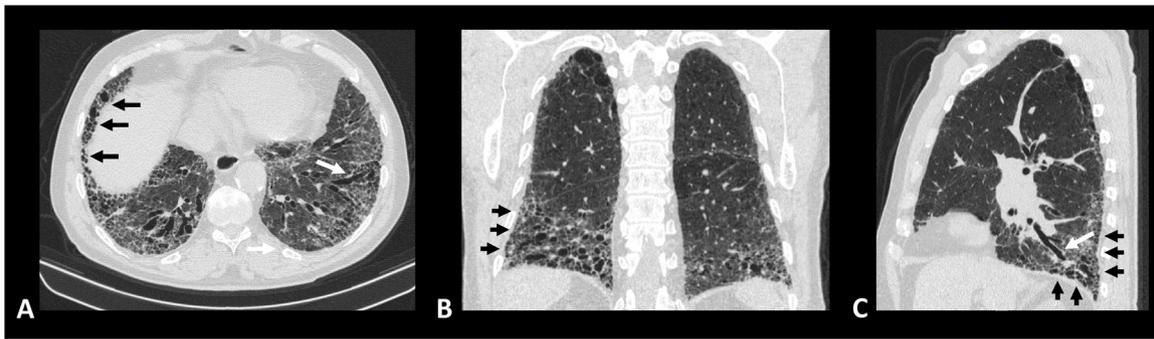

Fig. 1. Exemplary high-resolution computed tomography image displaying typical features of UIP-pattern in (A) transverse, (B) coronal and (C) sagittal view: architectural distortions with extensive honeycombing (black arrows) and traction bronchiectasis (white arrows) in predominantly basal and subpleural location.

biopsy is recommended to either confirm or exclude the diagnosis of IPF. Thus, HRCT plays a central role in the diagnostic workup of IPF.

In 2011, the American Thoracic Society (ATS), European Respiratory Society (ERS), Japanese Respiratory Society (JRS), and Latin American Thoracic Society (ALAT) presented a clinical practice guideline [8] that set the standard for radiologic diagnosis. In early 2018, a task force of the Fleischner Society [7] published a guideline that modified criteria for UIP taking into consideration the experience gathered with the 2011 guidelines in clinical practice. Finally, in September 2018, a new edition of the ATS/ERS/JRS/ALAT-guidelines was published [6]. Both recent guidelines converged to very similar categories for the diagnosis of UIP.

Recently, anti-fibrotic medication has become available that can delay progression of lung tissue destruction [Nintedanib [9] and Pirfenidone [10]]. Swift diagnosis is a prerequisite to establish therapy and potentially improve outcome in patients with IPF [1,4]. Due to the complexity of the task and the fact that IPF is a rare disease, a multidisciplinary cooperation of pulmonologists, radiologists and pathologists with a high degree of experience in ILD diagnosis is required [7]. Therefore, expertise is located particularly at medical centers specialized for ILD.

To ascertain accessibility to state-of-the-art diagnosis for patients that are primarily taken care of in hospitals remote from such centers, telemedicine is an option and is explicitly recommended by the Fleischner Society in the white paper on IPF [7]. Teleradiology is the exchange of radiological images and patient-related data between geographically remote locations for purposes of expert reading [11]. Compared with the United States, where teleradiology is an important economic factor [12], its application remains limited in Europe, especially in the cross-border setting [13]. There are some studies on national teleradiology projects in Europe [14–19] and other areas of the world [20–24]. However, there is only one study on a cross-border teleradiology project in Europe for knee and hip X-ray examinations [25]. It is therefore important to share experiences with cross-border teleradiology programs and derive recommendations for future projects.

As part of a collaboration framework with Boehringer Ingelheim and starting in January 2014, partner hospitals in Central Eastern Europe and Asia can send HRCTs of patients with suspected IPF to a university hospital specialized in diagnosis and treatment of ILD for a centralized expert consensus reading by a radiologist and a pulmonologist. In this study, we report our experience from this large cross-border teleradiology program.

2. Materials and methods

Informed consent was waived by the local ethics committee (Project ID: Req-2019-00403).

2.1. Data transfer, reading and reporting

Partner hospitals located in Central Eastern Europe and Asia were eligible to participate in the cross-border teleradiology program for a structured expert consensus reading of CTs with the clinical question of IPF. Chest CT scans were performed locally at the referring hospitals. There was no fixed protocol, but HRCT images with 1-mm transversal slices and lung kernel reconstruction were recommended on the submission platform. All communication, including the final structured reports, was in English. After registration, pulmonologists in partner hospitals receive a personalized upload link that is only valid for a short period and for the dataset of one patient. After confirming that patients consent is given and the data transfer complies with local regulations, data, including the patients` name, date of birth, and medical history is uploaded to the central expert reading site. Subsequently, the CT image data was transferred from the local PACS to the PACS of the central expert reading site. All data was uploaded via a secure communication protocol set up with a leading local IT-infrastructure service provider. A structured report according to the current guidelines was generated by a board-certified radiologist with 20 years of professional experience in cardiothoracic imaging (JB) and a pulmonologist with longstanding expertise in ILD (KH). Report templates were immediately updated by the teleradiology program coordinator (JB) in close cooperation with the specialized pulmonologist (KH) when revisions of international guidelines were published. Table 1 specifies which guideline was used in which period. Tables A.1 – A.3 in the appendix show the three structured report templates used in the respective periods. Finally, reports were sent back by encrypted email to the referring physician in the local hospital. All reports clearly stated the category of the prevailing pattern found in the HRCT scan according to the current guideline. In case of further questions, the physicians could contact the coordinator of the program by e-mail. Fig. 2 shows the workflow of the teleradiology program. The centralized expert consensus teleradiology program was not intended to make a final diagnosis or determine further therapy. This remains the task of the responsible local multidisciplinary panels, because it requires availability of all diagnostic and anamnestic information and interaction with the patients.

2.2. Technical image data and report data analysis

All data collected by the cross-border teleradiology program between 01/2014 and 05/2019 was analyzed (n = 703 HRCTs with corresponding reports and technical data). We evaluated basic patient characteristics (age and sex) as well as the geographic distribution of referring hospitals. Furthermore, we analyzed technical aspects like slice thickness, tube current (mAs) and peak kilovoltage (kVp). We determined whether the slice thickness of transmitted CTs complied with the recommendations defined by the Fleischner Society [7] and in the ATS/ERS/JRS/ALAT-guideline [6]. Furthermore, the number and reasons for technical problems that occurred during image data

Table 1
Study periods with guidelines and categories used.

Study period	Guideline	Literature	Categories
Period A 01.01.2014 – 08.05.2018	ATS/ERS/JRS/ALAT Guideline 2011	Raghu et al. 2011 [8]	(1) UIP (2) Possible UIP (3) Inconsistent with UIP
Period B 09.05.2018 – 11.09.2018	Fleischner Society	Lynch et al. 2017 [7]	(1) Typical UIP (2) Probable UIP (3) Indeterminate for UIP (4) CT-distribution/features most consistent with non IPF-diagnosis
Period C 12.09.2018 – 31.05.2019	ATS/ERS/JRS/ALAT Guideline 2018	Raghu et al. 2018 [6]	(1) Typical UIP (2) Probable UIP (3) Indeterminate for UIP (4) Alternative Diagnosis

transmission was determined by comparing the number of images sent by the referring hospital and received by the central reading site, thereby ensuring data integrity. The report turnaround time was analyzed in business days (Monday until Friday). A maximum turnaround time of 5 business days was envisaged. Whenever it was not possible to obtain specific information for a report (e.g. slice thickness), we documented the number and percentage of exams with missing data. These missing reports were then excluded from the specific sub-analysis. Finally, we compared the distribution of diagnoses in the three study periods A, B and C defined by the periods of validity of the respective guideline.

2.3. Survey

The survey comprised 8 questions and assessed satisfaction with and impact of the program and the structured reports that were generated within the context of the teleradiology program. The complete questionnaire is added to this study as Table B in the appendix.

2.4. Statistical analysis

Descriptive statistical analysis was performed with SPSS Version 22 (IBM Corp., Armonk, NY). No complex statistical calculations were conducted.

3. Results

3.1. Patient characteristics

Mean age of the patients was 63.7 years (standard deviation [SD]: 12.2 years). There were more men (n = 376; 53.5%) than women (n = 321). HRCTs were referred to the central reading site from 239 hospitals located in 46 cities in 12 countries: Russian Federation (n = 265); Romania (n = 123); Hungary (n = 113); Poland (n = 69); Latvia (n = 65); Croatia (n = 38); Estonia (n = 15); Bulgaria (n = 6); Switzerland (n = 4); Serbia (n = 3); Lithuania (n = 1); Czech Republic (n = 1). Fig. 3 illustrates the geographic distribution of the patients. In few cases, information was missing (age: n = 49 [7 %]; sex: n = 6 [1 %]; referring hospital: n = 7 [1 %]).

3.2. Technical image data analysis

The examinations were acquired at the participating hospitals on 56 different models of CT scanners from 7 different vendors (in alphabetical order): AGFA Healthcare (Mortsel, Belgium), Canon Medical Systems Corp. (Otawara, Japan), GE Healthcare (Chicago, IL, United States), Hitachi Medical Systems (Chiyoda, Japan), Philips Healthcare (Amsterdam, Netherlands), PNMS (Shenyang, China), Siemens Healthineers (Forchheim, Germany). Information on slice thickness
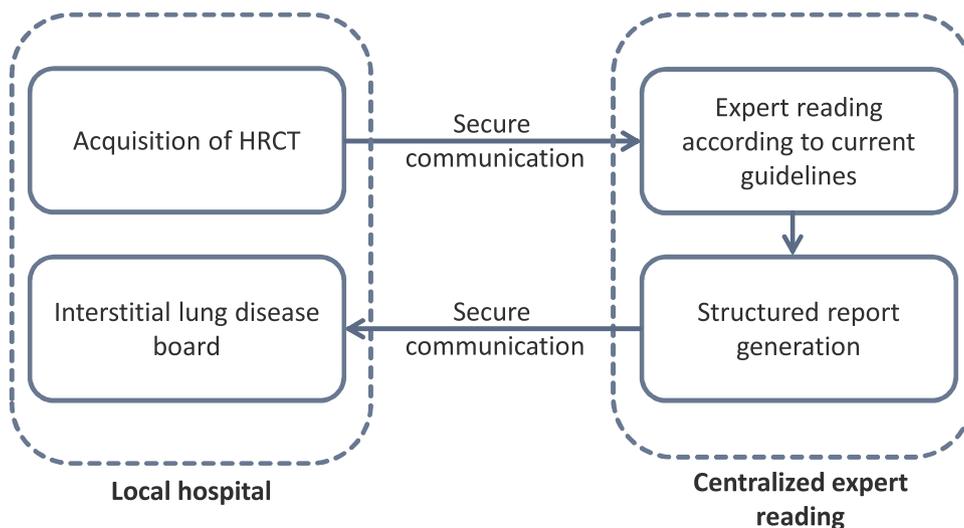

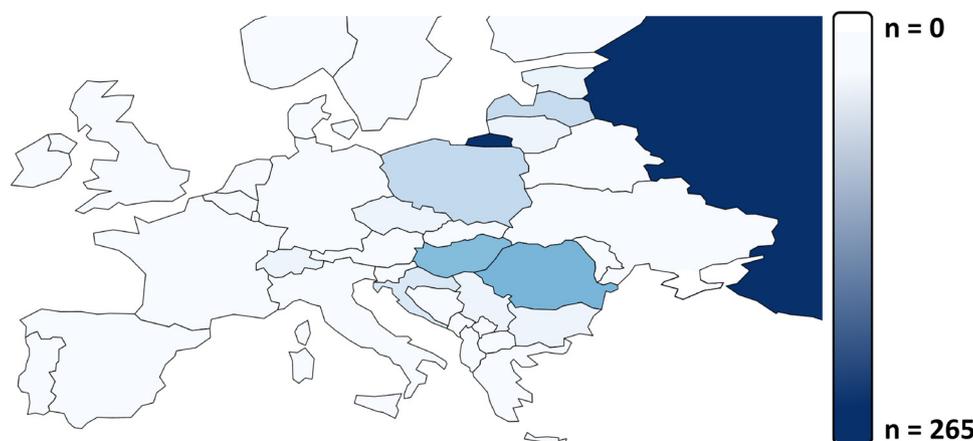**Fig. 2.** Workflow of the teleradiology program.

Fig. 3. Colormap illustrating the geographic distribution of HRCT-referrals by country. The color represents the number of cases referred to the central expert reading site between 01/2014 and 05/2019 from white (no referrals) to dark blue (265 referrals). Color scale on the right.

Table 2
Compliancy of CT scans regarding slice thickness with the two most recent guidelines for the diagnosis of IPF/UIP. Information on slice thickness was available for 96.7% (680/703) of scans.

Guideline	Publication	Recommended slice thickness	Compliant CTs (n [%])	Incompliant CTs (n [%])
Fleischner Society	Lynch et al. [7]	< 2 mm	526 of 680 [77.4%]	154 of 680 [22.6%]
ATS/ERS/JRS/ALAT	Raghu et al. [6]	≤ 1.5 mm	526 of 680 [77.4%]	154 of 680 [22.6%]

could be obtained for n = 680 HRCTs (96.7% of all scans). Mean slice thickness was 1.4 mm (SD: 0.7 mm). The compliance of the referred CTs regarding the recommendations for slice thickness is shown in Table 2. For both most recent guidelines, 77.4% of all referred CT scans were compliant. Mean tube current was 222.6 mAs (SD: 132.5 mAs) and mean peak kilovoltage 132.5 kVp (SD: 7.1 kVp). In some cases, information on tube current and peak kilovoltage could not be determined (9.8 % of all scans).

Image transmission errors occurred in 50 cases (7.1 %): in 19 cases (2.7 %), the transmission was incomplete meaning that only a fraction of images was transferred. In 31 cases (4.4 %), no image information at all was transferred. All issues were solved by direct communication with referring physicians and responsible IT engineers. Mean report turnaround time was 1.7 business days (SD: 2.9 business days). A total of 620 reports (88.2 %) were generated within five business days as envisaged.

3.3. Report analysis

Analysis of reports was split into three periods according to the validity of guidelines. In Period A (*01.01.2014 - 08.05.2018*), 172 out of 484 (35.5 %) CTs were classified as showing predominantly "UIP". This ratio of exams predominantly showing this radiologic pattern was slightly higher in period B (*09.05.2018–11.09.2018*) with 41.1 % "Typical UIP" (46 out of 112). In period C (*12.09.2018–31.05.2019)*, 27.1 % of CTs were classified as "Typical UIP" (29 out of 107). Altogether, 35.1 % of all referred patients showed the "UIP / Typical UIP"-pattern. Of these, the majority was male (64.0%).

Statistics regarding report analysis are shown in more detail in Table 3.

3.4. Survey

The survey response rate was 30.9 %. Of the participating physicians, 58.8 % worked for a university hospital, 35.3 % for a non-university hospital and 5.9 % for a private practice.

Mean overall satisfaction with the centralized IPF expert teleradiology program was 8.4 (out of 10; SD: 3.1). Quality of the reports

was rated with 8.2 (out of 10; SD: 3.2). Their impact on the clinical management of the patients was rated 9.0 (out of 10; SD: 1.7). Report turnaround time was evaluated as 9.4 (out of 10; SD: 1.5). The utility of the teleradiology program regarding the gaining of own expertise in IPF was assessed with 9.3 (out of 10; SD: 1.7) by the referring pulmonologists. The ease of uploading the images was rated 9.1 (out of 10; SD: 1.2). All referring physicians (100%) stated that they would recommend the centralized IPF teleradiology program to their colleagues.

4. Discussion

Referring pulmonologists worked for 239 hospitals in 12 countries. Despite great variance regarding localization of hospitals, deployed CT scanners and slice thickness of CTs, image transmission errors occurred in only 7.1 % of exams and were solved timely in cooperation with the referring sites and IT. Slice thickness of the CT scans was compliant with guidelines in 77.4 %. The defined maximum report turnaround time of 5 business days was met in 88.2 %, mean turnaround time was 1.7 business days. Overall, 35.1% of all CTs predominantly showed the radiologic pattern "UIP/Typical UIP". Of these patients, the majority was male, a fact in line with literature [26]. The survey demonstrated high rates of satisfaction of the referring sites with the centralized expert teleradiology program and that the teleradiology program helps referrers to build local expertise in IPF.

Only one previous study from 2010 dealt with a cross-border teleradiology cooperation in Europe: Ross and colleagues evaluated Baltic eHealth and R-Bay, two programs limited to knee and hip X-ray examinations [25]. Reports for 649 exams were generated. The authors identified language barriers as the biggest challenge for cross-border cooperation. Reports were partly in English and partly in local languages after translation by a translation engine. However, this translation engine failed in a relevant portion of reports so that interpreters had to translate reports in 20% of cases. In our teleradiology project, the working language for communication and reports was English only, which in our opinion is the best solution given the fact that English is the lingua franca of academics and healthcare. We found no problems with this approach. However, this might be due to the fact that we used fully structured reporting, an area for which Ross and colleagues

Table 3
Results of the report analysis regarding the finally diagnosed categories for each study period.

Study period	Guideline	Categories	n	%
Period A				
01.01.2014 – 08.05.2018	ATS/ERS/JRS/ALAT Guideline 2011	(1) UIP	172	35.54 %
		(2) Possible UIP	79	16.32 %
		(3) Inconsistent with UIP	233	48.14 %
			Σ = 484	Σ = 100 %
Period B				
09.05.2018 – 11.09.2018	Fleischner Society	(1) Typical UIP	46	41.07 %
		(2) Probable UIP	13	11.61 %
		(3) Indeterminate for UIP	22	19.64 %
		(4) CT-distribution/features distribution/features most consistent with non IPF-diagnosis	31	27.68 %
			Σ = 112	Σ = 100 %
Period C				
12.09.2018 – 31.05.2019	ATS/ERS/JRS/ALAT Guideline 2018	(1) Typical UIP	29	27.10 %
		(2) Probable UIP	9	8.41 %
		(3) Indeterminate for UIP	4	3.74 %
		(4) Alternative Diagnosis	65	60.75 %
			Σ = 107	Σ = 100 %

explicitly demand further research [25], and due to a narrow clinical question ("Is the predominant pattern UIP?"). Additionally, legal barriers might require that reports are written in the local language, especially in primary reporting. Another factor explicitly mentioned by Ross et al. is that of trust of partners. The results of our survey indicate that this trust can be built with a high reporting quality and reliable report turnaround times.

In the further course of discussion, we want to highlight five aspects that appear especially relevant to us: first, we found a ratio of transmission errors (7.1 %) that is in line with the study of Gray and colleagues that reported failure in 6 % of more than 750 emergency CTs transferred in a teleradiology program in Ireland [24] and superior to the 11 % found in an Austrian teleradiology project [16] and the 19% reported by Char et al. for an Indian teleradiology program [20]. They, as we, concluded that this low rate of transmission errors demonstrates robust performance of the teleradiology network. Second, we found a clear allocation of responsibilities and assignment of one program coordinator important for the success of our teleradiology program. In our case, the responsibility of providing all needed clinical information and the integration of the written CT report into the further workup of the patient was allocated to the referring pulmonologist, while the responsibility of state-of-the-art structured reporting according to current guidelines was the responsibility of the central expert reading site. The scope of the program should be clearly defined and responsive communication channels should be established in advance [27]. The importance of an effective management for teleradiology programs had been stressed elsewhere [22,28]. Third, our report turnaround time complied with the previous definition of a maximum of 5 workdays in 88.2 %. The absolute number of 1.7 workdays on average cannot be compared to previous studies on teleradiology programs due to different scopes of other programs, e.g. on emergency CT examinations [20,24]. However, a maximum report turnaround time should always be defined in advance and adhered to in order to enable workflow integration at the referring hospital. Our referrers were very satisfied with the report turnaround time (9.4 out of 10). Fourth, we used secured communication for image transmission in close cooperation with a telecommunication provider to ensure data privacy. By comparing the number of images that were sent from the referring hospital and received at the central reading site, we made sure that cases with no or incomplete data transmission could be followed up. Measures guaranteeing data integrity and data security should be central components of each teleradiology program [29–32], as also stated in ACR [27] and ECR [33] whitepapers on teleradiology. Fifth, we used fully structured report templates that were designed by the teleradiology program

coordinator in close collaboration with the IPF expert pulmonologist at the central reading site. Apart from other important arguments for structured reporting like improved report consistency [34], higher satisfaction rates of referrers [35] and better accessibility for the purpose of data mining [11], this is also an effective step enabling precise communication in cross-border teleradiology programs. In these, high-precision communication is vital because face-to-face communication of referrers and radiologists is often impossible. Moreover, in a cross-border context, it also enables reliable translation of reports into other languages: Sobez and colleagues demonstrated that translation of radiology reports based on structured reporting without significant loss of quality is feasible [36]. This idea is also supported by the ESR and ACR white papers on teleradiology [37]. Sixth, teleradiology programs can be more than just a diagnostic service. Besides the desired impact on the management of patients, our referrers also highly appreciated the effect of the program on building own local expertize regarding the diagnosis of IPF.

There are some limitations to our study: First, some data was missing (age, sex, exact referring hospital). However, this was the clear exemption (< 10% of all cases), which is why we do not expect a relevant bias. In the future, we aim at using a standardized input mask with mandatory input fields to guarantee completeness of data. Second, 22.6% of all CT series did not fully comply with the recommendations of the guidelines in respect of slice thickness, despite a clear statement on the upload platform of the teleradiology program. A potential remedy is to conduct a technical check at the upload stage based on the DICOM tag for slice thickness. If there is an attempt to upload non-compliant image data, the upload can be refused and the referrer immediately notified which data is required. Third, the response rate of the survey was quite low, which negatively affects the reliability of the derived conclusions. However, low response rates of online surveys are a common problem [38] and we did not calculate advanced statistics based on this data. The aim of the survey was to get a general impression of the satisfaction with and impact of the centralized expert consensus reading program. Fourth, we did not perform a thorough cost-effectiveness analysis at this stage.

5. Conclusions

This international expert reading program for CT in suspected IPF demonstrates the feasibility of cross-border teleradiology. Key factors for success of those projects are among others a previous definition of distinct responsibilities, the establishment of responsive communication channels, the usage of fully structured report templates and the

adherence to maximum turnaround times.

Data availability

The HRCT images are stored in our local PACS system and are – like all our patient data – subject to the strict data protection policy of our hospital. Upon request and after approval of our local ethics committee, the image data can be shared with interested researchers.

Patrizia Haegler is an employee of Boehringer Ingelheim (Switzerland) GmbH. She was not involved in study design and analysis. All other authors declare no conflict of interest.

Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ejrad.2019.108719.

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