Four-Year Experience of Digital Slide Telepathology for Intraoperative Frozen Section Consultations in a Two-Site French Academic Department of Pathology

Astrid Laurent-Bellue, MD,[1,2] Eric Poullier,[3] Jean-François Pomerol,[4] Eric Adnet,[5] Marie-José Redon,[1] Katia Posseme,[1] Olivier Trassard,[1] Daniel Cherqui, MD, PhD,[2,6] Kevin Zarca, MD,[7] and Catherine Guettier MD, PhD[1,2]

From the [1]Department of Pathology, AP-HP-Université Paris Saclay, Hôpital Bicêtre, Le Kremlin-Bicêtre, France; [2]Université Paris-Saclay, Faculté de Médecine, Le Kremlin-Bicêtre, France; [3]Information System Department, AP-HP, Campus Picpus, Paris, France; [4]TRIBVN Healthcare, Châtillon, France; [5]Information System Department, AP-HP-Université Paris Saclay, Hôpital Bicêtre, Le Kremlin-Bicêtre, France; [6]Department of Surgery, Centre Hépato-Biliaire, AP-HP-Université Paris Saclay, Hôpital Paul Brousse, Villejuif, France; and [7]URC eco Ile-de-France, AP-HP-Université Paris V, Paris, France.

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ABSTRACT

Objectives: *To share our experience with digital slide telepathology for intraoperative frozen section consultations (IOCs) and to describe its evolution over time by reporting performance metrics and addressing organizational and economic aspects.*

Methods: *Since 2013, a technician has been alone at the surgical site. At the other site, the pathologist opens the digital slide from a local server via the intranet. Three periods were compared: a 6-month period of conventional IOC (period 1), a 24-month period of telepathology at 6 months after implementation (period 2), and a 12-month period of telepathology at 3.5 years after implementation (period 3).*

Results: *In total, 87 conventional IOCs and 464 and 313 IOCs on digital slides were performed respectively during periods 1, 2, and 3; mean turnaround time was 27, 36, and 38 minutes, respectively, and there were a mean number of 1.1, 1.1, and 1.3 slides, respectively, per IOC. Diagnostic accuracy was achieved in 95.4%, 92.7%, and 93.9%, respectively, of IOCs (not significant). The additional cost is in the same range as the cost of urgent transport by courier.*

Conclusions: *Developing IOC with digital slides is a challenge but is necessary to optimize medical time in the current context of pathologist shortage and budget restrictions.*

Key Points

- Digital slide telepathology for intraoperative consultations is feasible in routine workflow and offers an adequate diagnostic accuracy rate but a slightly longer turnaround time.
- It represents a challenge for technical and medical teams.
- Digital slide telepathology meets the challenges of remote diagnosis for frozen sections, made necessary by the centralization of the departments of pathology in most countries.

Telepathology was first described in 1986 by Ronald Weinstein[1] as a tool to deliver pathology services over a distance using digital imaging processing and telecommunications. Telepathology has not yet been largely implemented for primary frozen section diagnoses, but interest in its use has increased because of the growing trends in most countries to centralize departments of pathology. Consequently, some hospitals no longer have an onsite pathologist to cover intraoperative frozen section consultations (IOC).

Hospital 1 and hospital 2 share the same academic department of pathology with a unique technical platform based in hospital 1 since 2008. Hospital 2 is a university hospital with a high level of activity in liver transplantation and hepatobiliopancreatic surgery. In 2008, the department of pathology registered 14,050 exams from hospital 1 and 4,320 exams from hospital 2. From 2008 to 2013, IOCs of hospital 2 were performed onsite by a pathologist dispatched from hospital 1 each day and assisted by a technician. Because of an important increase in the activity of the department, it was decided in July 2013 to implement telepathology using digital slide technology with only a technician present onsite for the IOC of hospital 2 to optimize medical organization. The sites are 2.7 km apart from one another, allowing easy backup in case of technical problems. This experience was temporarily part of a local Telepathology Pilot Network (November 2014 to January 2016).

Telepathology using robotic microscopes or, more frequently, digital slides has already been implemented for IOC coverage in different countries. At University Health Network in Toronto, Canada, an academic 4-site health care facility, digital slides have been used routinely for neurosurgical IOCs at 1 of the 4 sites for more than 10 years.[2] Nearly 20 experiences of telepathology for IOC have now been published since 2010 all over the world, with more than half using whole-slide image technology. As shown in a recently published study,[3] these experiences are different from one another regarding their design (prospective or retrospective), their technical equipment, their network architecture, their number and rhythm of daily IOCs, and their workflow organization. Moreover, the numbers and positions of the people involved in IOCs at the surgical site are largely divergent from one institution to another, involving pathologists,[4-10] technicians,[2,11-16] and residents.[16,17] In the reported experiences, the most frequent specimens targeted for IOC are brain tumors,[2,11,12,16] gynecologic organs and axillary sentinel lymph nodes,[6,13,15,18] thyroid glands,[18] lung resections,[14,19] prostate resections, and skin tumors for assessment of the margins.[15]

From our experience of telepathology for IOC in hepatobiliopancreatic surgery, which started in 2013 and is still a pilot in our country, we aimed with this prospective study, as defined by Wellnitz et al[20] and Dietz et al,[3] to report performance metrics over time such as turnaround time (TAT), accuracy rate, and technology failure rate and to discuss organizational aspects, cost, and cost-effectiveness of this diagnostic procedure.

Materials and Methods

Equipment, Software, Network Architecture, and Workflow of IOCs With Telepathology

The hospital 2 site was equipped throughout the study period with the A1R-ScanScope scanner with a 1-glass-slide capacity (Aperio; Leica Biosystems), piloted by a specific computer. The scanning procedure is performed at ×20 magnification exclusively. The whole slide is digitized and transferred into the imaging management system (IMS) (CaloPix; TRIBVN Healthcare) connected to the laboratory information system (LIS), common for both sites (Diamic; Infologic). Digital slides are immediately uploaded and stored in the local image server shared by both sites and located in hospital 1 **Figure 1**.

Both sites (ie, hospitals 1 and 2) are linked by an intranet system. The hospital 2 network allows a 10-Mb/s speed for slide transmission. The videomacroscopy system is based on a digital Sony camera (MacroByTRIBVN; TRIBVN Healthcare) installed on a macrostand and piloted by the IMS. The pathologist takes over the technician's computer via a remote connection using virtual network computing. This system allows the technician to ask the remote pathologist for help to sample the specimen through live macroscopic image sharing.

The pathologist workstation in hospital 1 is composed of a standard PC (ProDesk 600 G1, HP, RAM 8.0Go), with a Pentium (Intel) central processing unit running Windows 7 (Microsoft Corp), with 2 screens (SynCMaster 2243BW, Samsung, with 1680 × 1050 resolution): one to display digital slides and the other to display the LIS patient file. The whole-slide digital images produced and stored in SVS Aperio format are visualized with the CaloPix viewer.

Before the implementation of IOC with telepathology in July 2013, the pool of 15 technicians had a 6-month training period to get used to the telepathology procedure. During this training period, they performed conventional IOC in hospital 2 with a senior pathologist present onsite and digitized the frozen section slides at the same time.

Since July 2013, a technician has been present and alone onsite at hospital 2. All technicians work at the hospital 2 site with a weekly rotation. Every morning, the technician performs a testing procedure to ensure that the scanner, information technology (IT) network, and all connections are working properly. The tissue specimens for IOC are sent directly from the operating room to the pathology laboratory by elevator. The first step for the technician is to register the IOC case in the LIS. To save time, and if no sampling is needed from the specimen, the registration can also be done later during tissue freezing. If necessary, the technician can ask the remote pathologist for help to sample the specimen through the live videomacroscopy system. After freezing the sample in the SnapFrost (Excilone) at −40 °C, the frozen section is cut at 5 µm in a −20 °C cryostat and stained with hematoxylin, eosin, and saffron. The slide is digitized within the IMS file linked to the LIS file and transferred directly to the local server. On the other site, the pathologist on duty for hospitals 1 and 2 opens the digital slide through the IMS connected to the LIS and then calls the operating room by telephone for the IOC result and calls the technician back to relay instructions for fixing the sample and ending the procedure. Besides frozen sections, the

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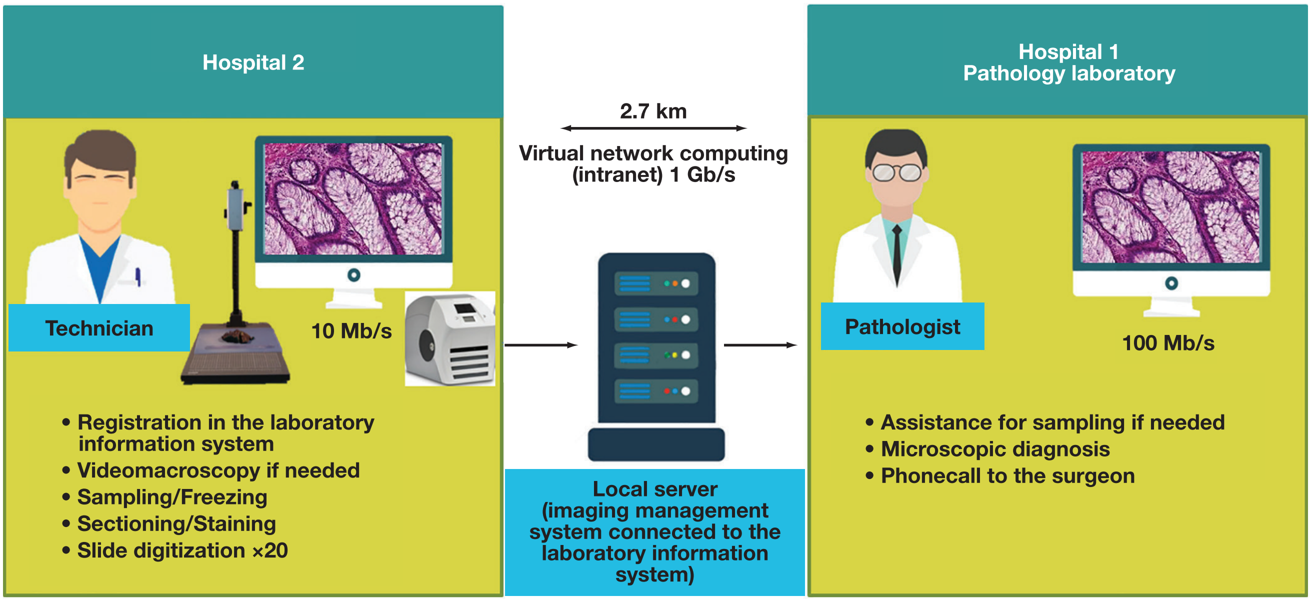

Figure 1 Equipment, software, network architecture, and workflow of intraoperative frozen-section consultations with telepathology.

technician in hospital 2 is also in charge of registering all samples in the LIS, managing the fresh surgical specimens, biobanking tissue samples, and sectioning paraffin blocks for the molecular pathology platform.

Our surgical colleagues were informed and agreed to adapt the course of their surgeries to this new organization.

Periods Under Review

Three periods of study were determined. The first 6 months (January to June 2013, period 1) comprised a control period of conventional IOC in hospital 2, just before the implementation of telepathology. The second period covered 24 months (January 2014 to December 2015) of digital slide telepathology for IOC between hospitals 1 and 2 at 6 months after implementation. The third period, consisting of 12 months (January to December 2017)—and the second period with digital slide telepathology for IOC—took place 3.5 years after implementation of telepathology. The first period of telepathology (period 2) can be considered a learning period, whereas the second period (period 3) was a period of routine operation.

Data Collecting for the 3 Study Periods

For each study period, the number of patients concerned, the total number of IOCs, and the number of slides for each IOC were collected. It is important to keep in mind that during a surgical procedure for 1 patient, the surgeon may need to ask for several IOCs. Moreover, an IOC may require 1 slide (eg, a peritoneal nodule) or more (eg, a small specimen of lymph node dissection with 2 or 3 distinct lymph nodes). Last, several surgeons may need an IOC at the same time. Informed consent was obtained from patients.

The characteristics of the specimen, indication of the IOC (diagnostic orientation, quality of the surgical resection, extension workup of a cancer), time of sample arrival in the laboratory, technical time for obtaining the stained frozen section, digitization time for both telepathology periods, and time of the result transmission to the surgeon were recorded for each IOC. The TAT was defined as the time elapsed between sample arrival in the laboratory and result transmission to the surgeon, no matter how many slides were necessary to obtain the diagnosis. Because many samples required multiple slides, we also calculated the TAT per slide. It was impossible, however, to assess the impact and time loss due to simultaneous IOCs (for the same patient or for different patients).

All incidents or breakdowns that potentially delayed IOC results were systematically extracted from the laboratory log book, including SnapFrost breakdown, cryostat breakdown, necessity of resectioning, necessity of redigitizing, scanner technical failure, and hospital IT network failure.

For each specimen, the IOC result was compared with the definite diagnosis performed on the paraffin section. The results were thus considered concordant (definite diagnosis identical to the IOC result) or discordant (all other results).

For discordant exams, the frozen-section glass and digital slides were systematically reviewed and compared with the corresponding paraffin section and, when

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Table 1
Numbers of Patients, Intraoperative Frozen Section Consultations (IOCs), and Slides for the 3 Periods

	Period 1 Before Implementation of Telepathology January to June 2013 (6 mo)	Period 2 Telepathology January 2014 to December 2015 (24 mo)	Period 3 Telepathology January to December 2017 (12 mo)
Patients	44	257	146
IOC	87	464	313
No. of IOCs/patient	2.0	1.8	2.1
No. of slides	97	526	406
No. of slides/IOC	1.1	1.1	1.3

Table 2
Indications for Intraoperative Frozen Section Consultations

	Diagnostic Orientation	Quality of the Surgical Resection	Extension Workup of a Cancer
Period 1, before implementation of telepathology, No. (%)	6 (6.9)	20 (23.0)	61 (70.1)
Period 2, telepathology, No. (%)	74 (15.9)	108 (23.3)	282 (60.8)
Period 3, telepathology, No. (%)	52 (16.6)	67 (21.4)	194 (62.0)

necessary, to the paraffin sections from the part of the specimen that was not examined during the IOC, in order to assess the quality of the sampling by the technician.

Financial Aspects

The specific investment for the implementation of telepathology between hospitals 1 and 2 was listed in detail, and the purchase prices for hardware equipment, scanner, camera, and software licenses were recorded. After a first-year guarantee, maintenance costs were calculated per year.

The annual logistical cost (depreciation and maintenance) based on a 5-year depreciation period was then calculated globally and on a per-act basis.

Both the average salary of a senior pathologist (ie, €120,000 [$133,509] per year and €65 [$72] per hour) and the cost of urgent transport between hospitals 1 and 2 (ie, €57 [$63] per ride) were collected for cost comparison.

Statistics

Statistical analysis was performed using the open access website BiostaTGV (Institut Pierre Louis UMR S 1136), which uses free R software. The Fisher exact test was used to assess the accuracy rate and the Student *t* test was used to compare the delays between different periods.

Results

Numbers of Patients, IOCs, and Slides for the 3 Periods

The numbers of patients, IOCs, and slides during the 3 periods are indicated in **Table 1**. The number of IOCs has increased steadily since the implementation of telepathology in 2013, with a monthly average number of 14.5 IOCs in 2013 vs 26 in 2017.

Indications for IOC

The most frequent indication for IOC was to assess the extension of a cancer. Next was evaluation of surgical resection, followed by diagnostic orientation **Table 2**.

The organs most frequently sampled in 2017 **Table 3** were (in decreasing order) peritoneum, lymph nodes, liver, biliary ducts, gallbladder, pancreas, and perivascular tissues.

Number and Nature of Technical Failures

The number and the type of technical failures that occurred during the 2 telepathology periods are listed in **Table 4**.

Technical failures due to scanner dysfunction or network outage (digital slide transfer failure or hospital IT failure) had an impact on 11% and 9.6%, respectively, of the IOCs during the first and the second telepathology periods.

Telepathology was not possible in 6 cases during period 2 and in 2 cases during period 3, and the pathologist had to move to hospital 2 to read the frozen sections. In 2 cases during period 2, the IOC was canceled because the surgeon could not wait longer for the answer. That situation did not happen during period 3.

TAT for IOC During the 3 Periods

Data on TAT were available for 52 of the 87 exams (59.8%) of period 1, 386 of the 464 exams (83.2%) of period

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Table 3

Breakdown of Specimens for Intraoperative Frozen Section Consultations

	Gallbladder and Biliary Ducts	Lymph Nodes	Peritoneum	Pancreas	Liver	Perivascular Tissues	Others
Period 1, before implementation of telepathology, No.	17	9	29	3	19	8	2
Period 2, telepathology, No.	73	101	133	35	98	15	9
Period 3, telepathology, No.	48	73	86	21	61	15	9

Table 4

Technical Failures During Intraoperative Frozen Section Consultations for the 2 Periods of Telepathology

	Total No. of Exams	Scanner Failures, No. (%)	Digital Slide Transfer Failure, No. (%)	Hospital Information Technology Failure, No. (%)
Period 2, telepathology	464	39 (8.4)	10 (2.2)	2 (0.4)
Period 3, telepathology	313	11 (3.5)	16 (5.1)	3 (1.0)

2, and 238 of the 313 exams (76.0%) of period 3 **Table 5** and **Table 6**. Data were unavailable for 2 reasons. The first reason is that the technician forgot to manually report the time of arrival of the specimen at the laboratory. The second reason, which occurred more frequently, was that the on-call pathologist forgot to manually report the time of the oral transmission of the result to the surgeon.

The average TAT was 27 minutes for conventional IOC, before the implementation of telepathology, and 36 and 38 minutes, respectively, for the first and the second telepathology periods. The difference in TAT was significant when comparing conventional IOC and telepathology ($P < .001$) but was not significant between the 2 periods with telepathology ($P = .04$). The average TAT per slide was 25 minutes during the conventional period and 33 and 32 minutes, respectively, during the first and second telepathology periods ($P < .001$) (Table 5).

The use of videomacroscopy for sampling the specimen concerned less than 5% of the cases during both telepathology periods.

By breaking down the TAT for 1 frozen section, the successive steps can be assessed for conventional and digital frozen sections (Table 6). Telepathology is inherently responsible for lengthening the TAT: the sampling by the technician, who is alone onsite and less experienced than the pathologist, needs a delay of up to an additional 5 to 10 minutes. The inevitable slide digitization and transfer require 3 to 6 minutes. And the interpretation of the digital slides, sometimes by younger and less experienced pathologists who may ask for a second opinion, adds an extra 5 minutes.

Table 5

Turnaround Time (TAT) for Intraoperative Frozen Section Consultations (IOC) During the 3 Periods

	Period 1, Before Implementation of Telepathology	Period 2, Telepathology	Period 3, Telepathology
No. of IOC	52	386	238
No. of slides	60	441	307
Average TAT/IOC (SD), min	27 (10)	36[a] (15)	38[a] (14)
Median TAT/IOC, min	26	33	36
IOC >30 min, %	30.8	57.5	71.0
IOC >40 min, %	3.8	27.2	37.8
Minimal TAT/IOC, min	14	15	15
Maximal TAT/IOC, min	45	90	89
Average TAT/slide, min	25	33[a]	32[a]

[a] $P < .001$.

Accuracy Rate

The results are detailed in **Table 7**. Complete concordance between the IOC result and the definite diagnosis on paraffin section was achieved in 95.4% of the conventional IOCs and in 92.7% and 93.9% of the IOCs with telepathology during periods 2 and 3, respectively (not significant, $P = .63$).

Most discrepancies were false-negative cases, sometimes with a tumor focus not visible on the frozen section and present only on the definite paraffin section (n = 8 during period 2 and n = 7 during period 3) or after inclusion of the whole fragment (n = 1, period 2). Only 1 discrepancy was related to an insufficient quality of scan, during period 2, with a blurred zone masking a focus of tumoral infiltration that was clearly visible on the physical frozen section slide but not on the digital slide. This problem did not happen again during period 3.

Cost-Effectiveness of Digital Slide Telepathology for IOC

Before the implementation of telepathology for IOC, the 2 sites were part of the same academic department

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Table 6
Timing of the Successive Steps for Conventional and Telepathology Intraoperative Frozen Section Consultations

Stages	Conventional, min	Telepathology, min
Reception of the specimen registration in the laboratory information system (sometimes during freezing time)	5	5
Sampling	0-5	0-10
Videomacroscopy	Not concerned	0-5
Sectioning	4	4
Staining	2	2
Digitization	0	1-3
Transfer to the server	0	2-3
Interpretation	1-5	1-10
Turnaround time	12-21	15-42

Table 7
Accuracy Rates for the Intraoperative Frozen Section Consultations Result and the Definite Diagnosis on Paraffin Section

	Period 1, Before Implementation of Telepathology, No. (%)	Period 2, Telepathology, No. (%)	Period 3, Telepathology, No. (%)
Accuracy	83 (95.4)	430 (92.7)	294 (93.9)
Discrepancy	4 (4.6)	34 (7.3)	19 (6.1)

of pathology and shared the same LIS interfaced with the same IMS, able to manage digital slides with an SVS format. Hospital 2 was equipped with a LIS workstation for specimen registration and a macroscopy bench. Both sites were connected by an intranet.

Additional investments and annual maintenance costs for the implementation of telepathology are described in **Table 8**. Additional investments included a digital camera controllable by IMS software for real-time view, a digitization workstation with a single slide scanner and image acquisition software, an IMS software license to control the digital camera and automatically index the images in the image database in connection with the patient record, and an interpretation workstation located in hospital 1 with LIS/IMS software licenses and 2 computer monitors. The 2 monitors allow the pathologist to consult the patient's previous examinations and analyze the IOC at the same time.

The annual maintenance costs were free for the first year after hardware and software purchase. For the digitization workstation, the annual maintenance cost was assessed at 13% of the purchase price.

The annual cost based on a 5-year depreciation period was then calculated globally and per act. Globally, it represents a yearly amount of €18,612 ($20,708). On a basis of 300 acts per year, the logistical cost of IOCs by telepathology is approximately €62 ($69); this sum represents a supplementary cost that needs to be added to the cost of a conventional IOC.

Overall, 313 IOCs were performed in 2017, with a mean number of 26 IOCs per month. For comparison, if a senior pathologist had to be present onsite at hospital 2 for an hour a day, just to cover IOC, it would represent a yearly salary of €16,380 ($18,224). This amount does not reflect either the time loss that would be caused by the journeys between the 2 hospitals or the inefficiency of this process (tiredness, inability to refocus rapidly, constraints for the operating room agenda). In contrast, if every IOC had to be driven from hospital 2 to hospital 1 by a courier, considering a yearly amount of 300 IOCs, then that would represent an extra cost of €17,100 ($19,025).

Discussion

The centralization of departments of pathology for economic and demographic reasons generates situations in which some hospitals no longer have an onsite pathologist to cover IOCs. Even if the distance between the centralized and affiliated sites is short, as in our case, a pathologist's travel from one site to another just to cover IOCs generates a loss of medical productivity. Alternatively, the presence of a full-time dispatched pathologist at the affiliated site produces the same consequences because this pathologist is away from the main laboratory activities that are performed at the centralized site. This increasingly frequent context implies a need for a means of remote diagnosis. First experiences were conducted using robotic microscopy,[2,5,8,11-14,16] but telepathology using digital slides rapidly appeared to be the most viable solution to meet the challenges of remote diagnosis for IOC.[2,6,7,9,10,14,15,18,19,21-23] Indeed, the development of telepathology for IOC is part of the health policy of some countries like China[18] and Luxembourg (Plan National Cancer 2014-2018).

So far, the reported experiences of telepathology for IOC have taken place in very different contexts. In some reports, telepathology is used only to support an onsite young or inexperienced pathologist who can ask for a remote second opinion.[8] In the majority of these experiences, however, telepathology is really used for remote diagnosis of frozen sections, but the technical equipment, the connection architecture, and the workflow organization are largely different from one study to another.

Table 8

Initial and Annual Maintenance Costs for Intraoperative Frozen Section Consultations With Telepathology

Cost	All Pices, All Taxes, € ($)
Initial investments for the implementation of telepathology	
Digital camera and macro software	11,452 (12,741)
Scan workstation (single slide scanner, imaging management system, and viewer)	41,000 (45,616)
Imaging management system software license to populate database with a link to laboratory information system	6,300 (7,009)
Pathologist interpretation workstation with laboratory information system/imaging management system licenses and 2 screens	3,500 (3,894)
Total capital expeditures	62,252 (69,260)
Annual maintenance costs after 1-y warranty	
Maintenance of macroscopic workstation	958 (1,066)
Maintenance of scan workstation	5,330 (5,930)
Maintenance of the imaging management system software to connect to the laboratory information system	707 (787)
Maintenance of pathologist interpretation workstation	707 (787)
Total expenses per year	7,702 (8,570)
Total expenses for a 5-y period	30,808 (34,280)
Annual costs (depreciation and maintenance) based on a 5-y period	**18,612 (20,708)**
Costs per act on a basis of 300 acts/y	62 (69)

Indeed, the practice of telepathology is not yet standardized, even at national levels. The publication of new experiences like ours, with large numbers of IOCs, different types of specimens from those reported in the previous experiences (ie, hepatobiliopancreatic surgery specimens), and long-term activity of digital slides for IOC will help define basic rules to ensure the quality of IOC with digital slides.

The use of telepathology for IOC between our 2 sites started in July 2013 and is now part of our routine workflow. The total number of IOCs for the 2 periods of telepathology was 777. The gradual increase in IOCs during the 4 years of the study, with a monthly average number of 14.5 in 2013 and 26 in 2017, is due to stronger surgical activity with the recruitment of new surgeons but also indirectly reflects the acclimatization of the surgeons to this new IOC procedure and their level of confidence after an initial period of concern.

In the current study, conventional IOCs from hospital 2 performed during the 6-month period just before the implementation of telepathology and IOCs performed with telepathology in 2 distinct periods—a learning and a routine period—1 year apart were compared for 2 main criteria: the TAT and the accuracy rate with the definite diagnosis on paraffin section.

IOC reporting is time sensitive. In our study, the average TAT for an IOC including 1 or several samples (1 or several frozen sections) was 26 minutes during period 1 and 36 and 38 minutes, respectively, during periods 2 and 3. The use of videomacroscopy accounted for less than 5% of IOCs and thus did not significantly affect the TAT for IOC performed by telepathology. This is probably due to the stereotyped nature of the samples sent in the context of a hepatobiliopancreatic surgery only, but it also reflects the qualification and composure of our technical staff. By looking in detail at the different stages, the difference in TAT between conventional and digital IOC is due to the scanning procedure (1-3 minutes), the digital slide transmission to the server (2-3 minutes), and the interpretation step, which is a little longer with digital slides. Because the technician is alone onsite, the technical actions (registering, sampling, sectioning, and staining the slides) can only be performed sequentially. In addition, the technician has other tasks to accomplish onsite, and those can interfere with the IOC, namely, with the constraint of the urgent samples that need to be sent to hospital 1 by the midday shuttle.

It is difficult to compare our TAT with telepathology with other studies. Recently published experiences of remote digital IOCs rarely provide precise and complete data regarding the TAT, with most giving information only about the digitization and/or the medical interpretation of the digital slides. When Dietz et al[3] did their review, only 7 of the 56 publications analyzed mentioned their TAT. Many studies do not mention their TAT at all. Our TAT for digital IOC is slightly longer than those reported in detail: 26.1 minutes,[11] 19.9 and 15.6 minutes,[2] 36.5 ± 1.65 minutes,[15] 29.7 minutes,[18] and 26 minutes for tumor samples and 31 minutes for graft evaluation.[24] These results could be explained partly by the specificities of our recruitment. Hutarew et al[11] and Evans et al[2] both report experiences with neurosurgery specimens. These samples are usually small and do not require sampling, and a single frozen section is usually enough. In contrast, hepatobiliopancreatic surgery, especially in a highly specialized tertiary center, requires numerous IOCs. During the resection of a perihilar cholangiocarcinoma, for example, the surgeon is likely to send peritoneal nodules,

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lymph nodes around the hepatic pedicle, and the 2 biliary sections for an IOC. Considering the important activity of the operating room in hospital 2 with 2 or 3 patients operated at the same time, the technician frequently received 2 or 3 samples for IOC at the same time and sometimes up to 10 samples in an hour. Simultaneous IOCs represented 40%, 46%, and 48% of all IOCs during periods 1, 2, and 3, respectively. The gradual increase in percentage reflects an evolution in surgical practices over the past 5 years, with the introduction of lymph node picking during pancreatic surgery and an increased complexity of surgical indications such as liver transplantation for patients with unresectable liver metastasis from colorectal cancer. These evolutions probably explain the slight increase in the average TAT per IOC between periods 2 and 3 with telepathology; however, the average TAT per slide (per frozen section) improved from 33 to 32 minutes when comparing periods 2 and 3, indicating that both the technician and the pathologist learned how to better manage this new procedure. The laboratory accreditation program from the College of American Pathologists requires 90% or more of single-block frozen sections to be reported within 20 minutes from the time the pathologists receive IOC specimens to the time the pathologists return the diagnosis to the surgeon.[25] However, this recommendation applies to IOCs with only 1 frozen section and is not universally accepted worldwide; for example, in China, the recommended TAT is within 30 minutes. It is noteworthy that our TAT for digital IOC is still shorter than the TAT of conventional IOC in some "pavilion" hospitals (eg, hospital 1) in which the operating theater is far from the department of pathology and tissue samples are sent by courier. Our surgeons have become used to this procedure for IOC and have reorganized the course of their interventions to account for a little longer TAT.

It is important to mention that the entire medical staff of our department of pathology takes part in this experience. This has 2 consequences. First, junior pathologists often need help from most senior pathologists at the beginning of the experience, especially for the hepatobiliopancreatic and lymph node IOCs. Pathologists used to ask colleagues for a second opinion in about 5% to 10% of IOCs performed by conventional microscopy compared with 20% of telepathology IOCs currently (ie, 2- to 4-fold increase). The need for a second opinion probably resulted in lengthened TAT. Second, as often reported in experiences implementing telepathology, some pathologists were initially reluctant regarding this new way of working. Total commitment and motivation of the medical staff is necessary if we want our TAT to improve and drop below 30 minutes.

Technical dysfunctions from computer, scanner, or network connections affected 11% and 9.6% of IOCs during periods 2 and 3, respectively. In the Chinese study by Huang et al,[18] technical failures are a main causes of IOC taking more than 60 minutes, aside from repeated frozen sections. However, almost 10% of technical dysfunctions remains too high after 5 years of routine operation. Even if, in our configuration, the pathologist can move from hospital 1 to hospital 2 within 15 minutes, we are currently working with the IT department to obtain an urgent intervention in case of network failure and to avoid untimely updates on critical computers. We bought a next-generation scanner that is easy to use, robust, and much more reliable than the previous one, with only 13 failures (ie, 4.7% of IOCs) in 2018, of which 5 were caused by the scanner. In parallel, we are putting pressure on our partner companies (scanner and software providers) for efficient hotlines to solve technical problems in minimal time.

Regarding diagnosis quality, several publications have already demonstrated the excellent concordance of the diagnostic results obtained with the glass slide and the digital slide analysis of the same frozen sections.[2,6,7,14,15,18,22-24] In this study, we assessed the accuracy rate of the IOC results and the definite diagnoses on paraffin section, and there was no significant difference between the conventional and both telepathology periods. Two things can explain why our accuracy rate is not above 95%, like two-thirds of the studies analyzed by Dietz et al.[3] First, in our design, we chose to include all discrepancies in discordant cases between the IOC results and the definite diagnoses, whether or not they affected therapy. Second, the organs we analyzed the most were (in decreasing order) the peritoneum, lymph nodes, liver, biliary ducts, gallbladder, and pancreas. No experience of hepatobiliopancreatic IOCs has been reported with telepathology, but these hepatobiliary specimens are known to be more difficult than others even with conventional IOCs. Indeed, some IOC samples in hepatobiliary pathology may be a source of pitfalls: biliary duct sections with distorted peribiliary glands vs infiltrative adenocarcinoma, pancreatic isthmus section with upstream pancreatitis vs infiltrative adenocarcinoma, subcapsular liver small nodules corresponding either to biliary hamartoma or biliary adenoma vs metastatic adenocarcinoma or cholangiocarcinoma. Moreover, Dietz et al[3] showed in their review that lymph node IOCs were the most difficult with telepathology, with a concordance weighted mean of 88.2%. Lymph nodes represented a large part of the specimens we analyzed, and our accuracy rate remained above 90%, like 82% of the studies analyzed by Dietz et al.[3] Interestingly, conventional IOCs during period 1 were analyzed by 3

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senior pathologists all trained in hepatobiliopancreatic pathology, whereas digital IOCs during periods 2 and 3 were analyzed by all department pathologists, most not specifically trained in this pathology. It is possible that a colleague's medical analysis of digital IOC maintains the same diagnostic quality as before the implementation of telepathology; however, as mentioned, it has slightly lengthened the slide interpretation time. Most discordant cases were false negative, reflecting the limitations of IOC for tumoral infiltration that may be visible only on deeper sections of the sample after paraffin embedding or inclusion of the whole fragment. Digitization and inappropriate sampling from the technician were each responsible for 1 error among the 777 IOCs.

Last but not least, in this period of financial restraint, the implementation of telepathology for IOC implies an additional cost that we evaluated at €62 ($69) per IOC based on activity of 300 acts per year, or an annual surcharge of €18,612 ($20,708). It would be difficult to value the gain in medical efficiency obtained with this new organization. However, we can set 2 things against those €18,612 ($20,708): (1) the salary equivalent of an hour a day of a senior pathologist's work and (2) the cost that would represent the urgent transport by courier of an average number of 300 IOCs per year from hospital 2 to hospital 1. These 2 amounts, respectively, €16,380 ($18,224) and €17,100 ($19,025), are actually in the same range as the estimated annual incremental cost.

Conclusions

Telepathology for IOC offers a high quality of services and allows optimization of the medical organization in the context of a shortage of pathologists and budget restrictions. Our work may be useful because it provides long experience of IOCs with telepathology and no onsite pathologist. It also offers a complete real-life overview regarding TAT, accuracy rate, cost-effectiveness, and logistical challenges. In the future, digital IOC will be included in the routine workflow of fully digital pathology.

Corresponding author: Catherine Guettier MD, PhD; catherine.guettier@aphp.fr.

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