Original Article

Dynamic nonrobotic telemicroscopy via skype: A cost effective solution to teleconsultation

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Abstract

**Context:** Skype is a peer to peer software application that has been historically used for voice and video calls, instant messaging, and file transfer over the Internet. Few studies are available using Skype specifically for telepathology. **Aims:** Our aim is to show that dynamic nonrobotic teleconsultation is possible and even effective via means of a standard microscope camera capable of live acquisition, Skype, an established broadband internet connection, and experienced pathologists. **Settings and Design:** Both the consulting “sending” pathologist and consultant “receiving” pathologist are reasonably experienced general surgical pathologists at junior attending level with several years of experience in sign out. Forty-five cases were chosen encompassing a broad range of surgical pathology specimens. The cases were prospectively evaluated with the consultant diagnosis used as a preliminary pathologic impression with the final diagnosis being confirmation. **Materials and Methods:** Versions of Skype 5.0 and above were used along with established broadband internet connections, usually between academic medical institutions. **Results:** Forty of forty-five cases (89%) were essentially concordant. In four of forty-five cases (9%), the consulting impression gave a differential, but favored an entity which did not match the final diagnosis. Only one case (2%) did the consulting impression not match the final diagnosis; a discordant opinion. **Conclusions:** The image quality via Skype screen sharing option is excellent. Essentially no lag time was seen. We have shown in our small pilot study that Skype is an effective cost-efficient means for teleconsultation, particularly in the setting of entity-related differential diagnoses in surgical pathology and when both the consulting and consultant pathologists are reasonably experienced.

**Key words:** Pathology, skype, telemedicine, telemicroscopy, telepathology

INTRODUCTION

Skype is a peer to peer software application that has been historically used for voice and video calls, instant messaging, and file transfer over the Internet. Skype is readily downloadable and basic service is free. Skype has a screen sharing option; making it an economical means of videoconferencing. Few studies are available using Skype specifically for telepathology.[1,2] Our aim is to show that without expensive robotic equipment or digital slide scanners, dynamic nonrobotic teleconsultation is possible and even effective via means of a standard microscope
camera capable of live acquisition, an updated Skype version, established broad band internet connections, and reasonably experienced pathologists.

**MATERIALS AND METHODS**

Both the consulting “sending” pathologist and consultant “receiving” pathologist were reasonably experienced general surgical pathologists at junior attending level at academic tertiary care centers with several years of experience in sign out. Forty-five cases encompassing a broad range of surgical pathology specimens were selected including some hematopathology and neuropathology cases. The cases were chosen for both second opinion as well as proof of concept. The cases involved recognizing specific entities or enlisting morphologic differentials. Our study did not include cytology cases or cases in which the diagnosis had to be established based on a threshold. For instance, determining whether a lesion was low or high grade, or whether superficial invasion is present was not included in this study. With “threshold” diagnoses, our opinion was that even without teleconsultation such cases are prone to subjectivity and interobserver variability. The cases were prospectively evaluated with the consultant diagnosis used as a preliminary pathologic impression with the final diagnosis being confirmation after the case had been thoroughly worked up.

The consulting impression was compared to the final diagnosis by categorization into the following four tiers:

1. Whether the consulting impression was definitive and matched exactly the final diagnosis.
2. Whether the consulting impression was not definitive but favored entities that were in the final diagnosis.
3. Whether the consulting impression was not definitive but was phrased in such a manner that was not discordant, despite favoring entities not in the final diagnosis.
4. Whether the consulting impression was discordant; either being too definitive that the final diagnose did not match or the consulting impression was clearly incorrect.

We considered cases which met criteria for tiers 1 and 2 essentially concordant, with tier 3 being neutral, and tier 4 being clearly discordant. Versions of Skype used in this study were Skype 5.0 and above. Only well-established broadband internet connections were used between two academic institutions in the United States and Europe. Connections from local “hotspots” were avoided where internet connections were potentially tenuous. Internet transmission speeds ranged usually from 1.0 Mbps to 2.0 Mbps, but at times ranged up to 15.0 Mbps.

The sending “consulting” microscope was an Olympus BX41 with standard Plan Objectives. A SPOT Insight Wide-field 4 Mp CCD Scientific Color Digital Camera was used for capturing images. Live images were displayed on the local desktop using the SPOT Advanced Software Version 4.7. Through the Skype Screen Share option, the receiving “consultant” pathologist is able to view the sending “consulting” pathologist’s screen with the images live captured in the SPOT Advanced Software. As with all dynamic nonrobotic means of telemicroscopy, the sending pathologist drives the glass slide. Communication between pathologists is easily performed via computer microphones, headsets, and/or speakers through Skype. Standard monitors and video cards are used which are capable of screen resolution of 1024 × 768 at 32 bit color.

**RESULTS**

A screenshot of a case with the Skype screen sharing option is shown in Figure 1. Description of the cases, encompassing the broad range of surgical pathology, is listed in Figure 2 along with the consulting impression and final diagnosis. No cytology cases which included papanicolaou or diff-quick stains were included. Four central nervous system cases and three hematology cases were included to encompass the broad range that general surgical pathology practices sometimes get on sign out. All seven of these hematology and neuropathology cases, the consultation impression were made on frozen section and/or touch prep. With the hematology cases, all were lymph nodes with bone marrows and smears excluded. In thirty-five of the remaining 38 cases, the consultation impression was made on nonfrozen biopsy or resection specimens and without information on ancillary immunohistochemical or molecular tests. Three of these remaining 38 cases were from the thyroid where the consulting impression was made on frozen sections; unfortunately standard practice at both institutions. Average time per consultation was 10 minutes and...
included discussion of age, gender, and anatomic location only. Names, identification numbers, and other clinical information were not discussed. Transmitted images included only the microscopic sections with no other portion of the slide, such as the label, visible to the other pathologist.

The cases, as listed in Figure 2, are also distinguished by font color according to the tier corresponding to how the consulting impression and final diagnosis compared. Twenty-five of 45 cases (56%) had the consulting impression match exactly the final diagnosis (tier 1). In addition, 15 of 45 cases (33%), the consulting impression gave a differential and favored a diagnosis, which after workup became the final diagnosis (tier 2). This essentially makes 40 of 45 cases (89%) concordant. In four of forty-five cases (9%), the consulting impression gave a differential, but favored an entity which did not match the final diagnosis. However, the morphologic differential of the consulting impression was phrased in such a generic means that there was not a discrepancy (tier 3). In only one case (2%) did the consulting impression not match the final diagnosis; a discordant opinion (tier 4). These results are summarized in Figure 3. As with Figure 2, different font colors distinguish various tiers.

| Anatomic Site            | Consultation Impression                                                                 | Final Diagnosis                        |
|--------------------------|----------------------------------------------------------------------------------------|----------------------------------------|
| Gastrointestinal/appendix| 1. Goblet cell carcinoma  
2. Mucinous adenocarcinoma  
3. Signet ring adenocarcinoma  
4. Paneth-like metaplastic carcinoma with giant cells | 1. Goblet cell carcinoma  
2. Mucinous adenocarcinoma  
3. Signet ring adenocarcinoma  
4. Paneth-like metaplastic carcinoma with giant cells |
| Central Nervous System   | 1. Meningioma with epithelial features  
2. Glioblastoma multiforme  
3. Schwannoma  
4. Dermatofibrosarcoma protubersans | 1. Meningioma with epithelial features  
2. Glioblastoma multiforme  
3. Schwannoma  
4. Dermatofibrosarcoma protubersans |
| Head and Neck            | 1. Favor carcinoma with squamous cell carcinoma and adenoid cystic carcinoma features  
2. Pleomorphic adenoma  
3. Warthin’s tumor  
4. Papillary thyroid carcinoma  
5. Adenoid cystic carcinoma  
6. Basaloid tumor, favor adenoid cystic carcinoma | 1. Papillary thyroid carcinoma  
2. Pleomorphic adenoma  
3. Warthin’s tumor  
4. Papillary thyroid carcinoma  
5. Adenoid cystic carcinoma  
6. Basaloid tumor, favor adenoid cystic carcinoma |
| Lung                     | 1. Adenocarcinoma, extensive lepidic growth  
2. Metastatic adenocarcinoma with eosinophils and clear cell features | 1. Adenocarcinoma, extensive lepidic growth  
2. Metastatic clear cell renal cell carcinoma |
| Testis                   | 1. Mixed germ cell tumor, predominantly choriocarcinoma  
2. Favor welsh cell tumor | 1. Mixed germ cell tumor, predominantly choriocarcinoma  
2. Welsh cell tumor |
| Kidney                   | 1. Renal cell carcinoma, unclassified-clear cell variant  
2. Mixed epithelial stromal tumor  
3. Epithelial angiomylipoma  
4. Acquired cystic disease-associated renal cell carcinoma  
5. Multinucleated renal cell carcinoma  
6. Chromophobe renal cell carcinoma  
7. Papillary renal cell carcinoma | 1. Translocation-associated renal cell carcinoma  
2. Mixed epithelial stromal tumor  
3. Epithelial angiomylipoma  
4. Acquired cystic disease-associated renal cell carcinoma  
5. Multinucleated renal cell carcinoma  
6. Chromophobe renal cell carcinoma  
7. Mixed tubular and oncocytoid cell carcinoma |
| Pelvic Mass              | 1. Adenosquamous carcinoma, spindle cell variant  
2. Serous carcinoma  
3. Brenner’s tumor  
4. Clear cell adenocarcinoma  
5. Favor malignant mixed tumor | 1. Adenosquamous carcinoma, spindle cell variant  
2. Serous carcinoma  
3. Brenner’s tumor  
4. Clear cell adenocarcinoma  
5. Mixed malignant mixed tumor |
| Hematology               | 1. Breast - Small round blue cell tumor, favor lymphoma  
2. Cervical lymph node - Small blue cell tumor, favor lymphoma  
3. Lymph node - plasmacytoid lymphoma, favor plasmacytoma | 1. Breast - Chromo lymphocytic leukemia  
2. Cervical lymph node - Marginal zone lymphoma  
3. Lymph node - plasmacytoma |
| Thyroid                  | 1. Anaplastic carcinoma  
2. Favor medullary carcinoma  
3. Follicular neoplasm, favor papillary carcinoma/follicular variant | 1. Anaplastic carcinoma  
2. Medullary carcinoma  
3. Follicular adenoma |
| Breast                   | 1. Metaplastic carcinoma  
2. Medullary carcinoma, poorly differentiated  
3. Apocrine carcinoma | 1. Metaplastic carcinoma  
2. Medullary carcinoma, small and large cell  
3. Apocrine carcinoma |
| Urinary Bladder and Urethra| 1. Clear cell adenocarcinoma  
2. Adenocarcinoma, intestinal type, not otherwise specified | 1. Clear cell adenocarcinoma  
2. Adenocarcinoma, intestinal type, not otherwise specified |
| Soft Tissue              | 1. Renal cell carcinoma  
2. Retropertioneal liposarcoma with dedifferentiation  
3. Low-grade myxoid neoplasm, favor cellular myxoma | 1. Retropertioneal liposarcoma with dedifferentiation  
2. Low-grade myxoid myositis sarcoma |

Figure 2: All forty-five cases are listed according to subspecialty/organ system. The consulting impression is compared with the final diagnosis. In the cases in light blue, the consulting impression gave a differential and favored a diagnosis which, after workup, became the final diagnosis. In the cases in purple, the consulting impression gave a differential, but favored an entity which did not match the final diagnosis. In case in red font, the consulting impression was discordant.
DISCUSSION

Static image telepathology for consultation remains commonplace for much of the world including developed countries. This often takes place through email transmission with attached static images. Several websites such as www.pathxchange.org/ (PathXchange), http://www.ipath-network.com/ipath/ (iPath), and https://pathconsult.upmc.com/ (University of Pittsburgh Medical Center Telepathology Consultation Service) facilitate sharing and/or consultation via static images. But with static image telepathology, there is also a lack of interactive communication in real-time. Consultation is constrained by the consultant pathologist selecting the correct area of interest and providing appropriate context for the case. Thus the diagnostic skill required at the sending site is rather high. This pressure is further compounded in areas of the world where there is scarcity of medical personnel with skills in histopathology.\(^1\)

Considering that much of the world lacks skilled pathologists, dynamic telepathology offers a better solution to static images. This is because with dynamic telepathology, less diagnostic skill is needed from the sending site. Dynamic telepathology is achieved via robotic and nonrobotic means. By robotic means, the consultant pathologist is able to remotely maneuver the slide at the sending site. This does require a robotic telepathology microscope at the sending site and this in turn adds additional cost for such a system. Nonrobotic dynamic telepathology is less expensive since a robotic microscope is obviously not required. But it does require coordinated viewing between two people. Under ideal conditions, this would be a skilled pathologist at the sending site maneuvering the slide to show a consultant pathologist at another location. Most systems also require video servers which have web serving capabilities to receive video signals and mediate transmission to the intranet or internet.\(^1\) For certain areas of the world without adequate funds, this need for a video server in performing nonrobotic dynamic telepathology adds another overhead cost in capital equipment.

The solution to obviate the need for video servers is nonrobotic dynamic telepathology using web conferencing software. Web conferencing solutions such as WebEx by Cisco are available but at subscription fees (around $500 annually). This is not ideal for poorer areas of the world without a fee exemption. We chose Skype because it was free and downloadable anywhere in the world. Requirements for both hardware and software are reasonably minimal. There are no subscription fees unless a group video calling option is employed (approximately $10 monthly). Another advantage of Skype, like WebEx, is the capability of viewing the image on mobile devices such as smartphones and IPAD-like devices. We unfortunately did not explore this feature in our study, but encourage further investigation into the feasibility of Skype mobile platform telepathology in the future.

With Skype, because a video server is not required, the costs for our nonrobotic dynamic telepathology system go to a microscope with adequate optics, a camera capable of real-time live capture, and reasonable internet broad band connectivity. With cameras, there are many.

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**Figure 3: Summary of the concordance rates according to tiers**

| Comparison between consultation impression and final diagnosis                  | Cases | Percentage |
|---------------------------------------------------------------------------------|-------|------------|
| Tier 1 – Consultation impression in exact agreement with final diagnosis        | 25/45 | 56%        |
| Tier 2 – Consultation impression favors in agreement with final diagnosis       | 15/45 | 33%        |
| Tier 3 – Consultation impression not discordant, but favors in disagreement with final diagnosis | 4/45  | 9%         |
| Tier 4 – Consultation impression discordant with final diagnosis                | 1/45  | 2%         |
available excellent older unused cameras, which range around one to two thousand dollars capable of this real-time live image capture. In addition, many institutions in developed world already have such devices. With many technologically savvy institutions going to digital slide teleconferencing, such devices appear to them as antiquated. We potentially see a future whereby a philanthropic system is created for such advanced institutions to donate such antiquated cameras to poorer regions of the world in order to construct inexpensive telepathology systems such as ours.

The purpose of our study was more than just validation but to show the proof of concept that nonrobotic dynamic telepathology using Skype is possible. With standard equipment and experienced pathologists, good concordance rates are achievable. There have been two prior published articles using Skype for telepathology.[2,3] Klock et al. described a telepathology system similar in construction to ours using both Skype and MSN. Bandwidth speeds were nominal, varying from 400 Kbs to 2.0 Mbs. In their publication they stated they were successful in using this system for interdepartmental specialist and frozen section consultations although no data were given to evaluate for quality assurance.[2]

Wamala et al. used a robotic telemicroscopy system with Nikon Coolscope; and therefore the need for a consultant pathologist to drive and select areas of interest was obviated. In this study, Skype was used for real-time communication between the consulting institution and consultant and not for image transmission. They were able to show quality assurance numbers at 97% agreement with the final diagnosis.[3]

Based on the four-tiered system we used to evaluate concordance, we had overall 89% concordance. Of that subset, 25 of 40 cases (63%) had the consultation impression match exactly the final diagnosis. A large number from this subset, 15 or 40 cases (37%) favored entities which eventually after ancillary testing and additional permanent sections became the final diagnosis. Examples from these 15 cases include chronic lymphocytic leukemia, marginal zone lymphoma, adenoid cystic carcinoma, synovial sarcoma, and sarcomatoid carcinoma; diagnoses which either were made on frozen section or required ancillary studies and/or better permanent section morphology for confirmation. We argue that had the consultation been performed by standard microscopy, similar rates would have still been obtained since we felt that visual quality and lag time of our telemicroscopy system were not the limiting factors.

Of the four cases which the consultant impression favored an entity not in the final diagnosis, two were salivary tumors, one a thyroid tumor, and one a soft tissue tumor. With the salivary tumors, one was a rare basaloid adenocarcinoma and the other was a basaloid cribriform proliferative tumor which was initially favored to be adenoid cystic and later was diagnosed as polymorphous low grade adenocarcinoma. Both were incredibly difficult diagnoses and entities which often get misdiagnosed without expert opinion or ancillary studies such as myoepithelial and c-kit immunohistochemical markers. With the thyroid tumor, a follicular variant of papillary renal cell carcinoma was favored, however the consulting impression was made on frozen section and touch prep; arguably an unrecommended practice but one performed at both institutions historically nonetheless. Therefore there was the disadvantage of lack of additional sectioning and good cytomorphology on the actual frozen slide; necessary in making the diagnosis. The one discordant case was a mucinous tubular and spindle cell carcinoma of the kidney which was the preliminarily called a papillary renal cell carcinoma. This is a rare but known diagnostic pitfall in genitourinary pathology. The diagnosis was achieved via the presence of a focal myxoid stromal area not shown or appreciated during the time of initial consultation. This re-illustrates the disadvantage of a nonrobotic dynamic telepathology system. In this case, the field of interest needed for the diagnosis was not emphasized or shown by the pathologist driving the slide. We argue that having a 2% discordant rate was not attributable to image quality but rather misdiagnosis due to how the case was presented by the consulting pathologist. Moreover, we argue that such a discordant rate would be no different than what would be obtained from standard multi-headed scope “cursing” or consensus conference-style consultation. Such errors occur in these situations since the consultant pathologist sometimes is not the slide driver but rather the passive participant, relying on the consulting pathologist to point out key regions.

Our study showed very good concordance rates and excellent image quality using the Skype screen sharing option. As mentioned previously, our one discordant case was not due to image quality but rather area of interest selection; a known weakness of nonrobotic dynamic telepathology. We had reasonable broadband connectivity with no lag time, lapses, or stalls. We admit our concordance rate between the consultation impression and final diagnosis was high. We felt there were several contributing factors as will be discussed.

Both pathologists in our study were English speaking and reasonably experienced in general surgical pathology. Both were able to recognize areas of importance and generate good interactive discussion of the cases at time of consultation. Not having a skilled driving pathologist providing context and showing critical regions of the slide would theoretically lower the concordance rates. This is a consideration if and when future similar studies are reproduced from underserved areas of the world. Expected such high concordance may not be
reasonable considering issues with language and scarcity of reasonably skilled pathologists driving the slide and provided context.

The ability to have good interactive discussion should not be understated. Many of our cases required good interactive discussion at the time of consultation. Both pathologists were able to communicate effectively between each other in real-time using Skype. This is not possible when static images are sent via email. Moreover this real-time voice communication of Skype via speaker and/or headset is a capability that robotic dynamic telepathology and digital slide systems as standalones lack as integrated features. As with the system as described by Wamala,[3] real-time voice communication is achievable with such systems only with the addition of a phone-line or internet based messaging system such as Skype of MSN messenger.

As a related matter in discussing our concordance rates, we wanted to address our reasons for including cases which were strictly entity related. This is opposed to including threshold diagnoses. By stating entity related, we mean diagnoses involving questions about tumor type. Since our study was more for proof of concept, we felt that introducing another variable such as interobserver variability would then confound concordance rates. Interobserver variability has been a long known problem in surgical pathology, and particularly in cases involving threshold diagnoses. Take for instance two scenarios of threshold diagnostic dilemmas: 1) the diagnosis of adenocarcinoma in small atypical foci of the prostate gland and 2) whether atypical proliferative breast foci represent in situ carcinoma. Disagreement rates even among expert pathologists have been published and known to be high with standard microscopy. By including such cases in our study, we argue that this would increase discordant rates due to this interobserver variability. This thereby clouds the true effectiveness of Skype in telepathology by introducing a problem that plaques both standard microscopy as well as telepathology. That stated, another study addressing threshold diagnosis should be performed, and it would be interesting to see how Skype affects the interpretation of such threshold diagnoses when compared to what has been historically published with standard microscopy.

An advantage of Skype is quality assurance when combined with applications such as “Pamela Call Recorder,” “Pamela for Skype,” or “PrettyMay Call.” These applications are able to record the sessions and even take notes during a call. We admit that our study did not use such an application. It was only much later after our study was completed that we became aware of their existence. The power of having such tools also cannot be understated. By being able to record, one can review the session and retrospectively and objectively critique problems which occurred at the time of consultation without the bias of recall. For instance, if a misdiagnosis were to be made by a consultant pathologist, then the reasons for why this occurred can be retrospectively analyzed. If certain areas of the slide were omitted by the consulting pathologist, this may relieve some of the burden of the consultant pathologist in the misdiagnosis. Further, the context of the conversation such as discussion of clinical history and external factors can be also reviewed to see if lack of information played a role in the misdiagnosis. In a way, this becomes the pathology consultation analogue to the “blackbox” recorder on airplanes. Furthermore, if there is a difficult case for which a variety of expert opinions are required, each session can be made available to the other consultants in order to aid in the diagnoses. We feel this one feature makes use of Skype in telepathology superior to standard microscopy for consultation.

We saw the use of this modality for telepathology being useful at least initially for underserved countries, where pathology is nearly nonexistent and security concerns take a backseat to just being able to deliver diagnostic care. Our study was conducted between two tertiary care academic institutions located in the United States and Europe and the information which was transmitted did not include any identifying information. Currently there are no journal articles on how HIPAA relates with Skype and telepathology. What is known is that Skype does not use or access the protected health information (PHI) transmitted using Skype software. Skype being not initially designed for telemedicine considers itself merely a conduit for transporting information, much like the electronic equivalent of the U.S. Postal Service or a private courier. Skype is not a business associate subject to HIPAA, nor are there current contractual arrangements with covered entities to create HIPAA compliant privacy and security obligations. Skype does have a variety of physical, technical and administrative safeguards aimed at protecting the confidentiality and security of the PHI that may be transmitted using Skype’s calling and video calling products. Such measures arguably meet HIPAA standards. Calls via Skype are very strongly encrypted, and the same is true of shared files, chats, and video. Skype uses AES (Advanced Encryption Standard) used by the U.S. Government to protect sensitive information and also uses the maximum 256-bit encryption. User public keys are certified by the Skype server at login using 1536 or 2048-bit RSA certificates. Downloads of Skype software through the Skype client or the Skype website also do not contain any spyware or malware.[4,5] In this article, our aim was proof of concept. We wanted to show the ease and feasibility of inexpensively delivering quality diagnostic second opinion as opposed to robustness of security. It is not known whether this modality of telepathology will catch on. Provided it does, it is acknowledged that the looming security and
regulatory issues will have to be addressed, but in future publications.

Another hurdle in the use of this Skype in telepathology is reimbursement; an obstacle of telemedicine in general and just not telepathology. For numerous reasons currently, telepathology lacks good reimbursement models. This is a topic which we can only provide our small perspective. Our study was done in courtesy between international academic institutions, with no compensation requested or given for the expert opinions. This is not uncommon with international consultations. There are no mechanisms established or negotiated by insurance companies or governmental bodies to relay payment. In order to aid underserved countries, we envisioned telepathology consultation via Skype as a courtesy service by expert pathologists who are willing to donate their eyes and time. Within the United States, how telepathology in general will get reimbursed is a complex question. The issue is ever evolving issue notably because it is subject to tenuous status of U.S. healthcare reform whose consequences have yet to be understood and felt. Moreover, even if there were to be a billing infrastructure for telepathology, Skype lacks any administrative software to be able to track the procedural intricacies required for billing. That stated, the fact that it is inexpensive is the advantage for Skype compared to other telepathology modalities such as digital slide scanning. Even if reimbursement were to remain low, the amount of capital investment required to provide such a valuable service is also low.

CONCLUSION

In conclusion, we have shown that Skype is an effective cost-efficient means for teleconsultation, particularly in the setting of entity-related differential diagnoses in surgical pathology. Ideally the best concordance rates are achieved when both the consulting and consultant pathologists are reasonably experienced taking advantage of the real-time voice communication of Skype. Our study also introduces possibilities for new investigation. Future investigations include validation of this system in how it translates to cytology and peripheral smears, the effectiveness of this system in group viewing, the applicability of this system with threshold diagnoses and quality assurance validation, and most interestingly how the system performs on mobile device platforms.

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