Telehematology Trials using the Sysmex LAFIA, Blood Cell Image Filing System

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In the pathological testing field, applications of Telepathology have been extensively examined, but in the blood testing field, applications for support of diagnosis and medical care using electronic cell images has yet to be significantly implemented. However, for blood testing, the potential for both intra-hospital and inter-hospital support of medical care and diagnosis utilizing blood cell images is greatly anticipated. We are undertaking an investigation of Telehematology using the Sysmex LAFIA, Blood Cell Image Filing System. For Telehematology utilizing intrahospital networks, image information previously available only in the laboratory, will become available throughout the hospital network, supporting clinical decision making. In addition, by building up networks between hospitals, transfer and referral of blood cell images becomes possible. For example, in hospitals where no clinical technologists or specializing physicians reside, doctors could consult with experts at remote hospitals, concerning cell image diagnosis. In particular, it is expected that realization of image consultation for remote diagnosis will greatly assist blood disease related medical care. Further advancement of Telehematology is expected with the streamlining of network environments in the future, and further investigation into security issues and the protection of patient information.

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Key Words Telehematology, Image Consultation, Blood Cell Image Filing System, LAFIA

INTRODUCTION

Hematology testing together with pathological testing is highly dependent on morphological tests, and evaluations of peripheral blood smears and bone marrow smears are essential for diagnosis of diseases including those of the blood. However, morphological analysis requires considerable skill, and in order to carry out accurate diagnosis of blood tests, medical laboratory technicians, clinicians specializing in blood, as well as hematologists are required. Adopting Telepathology in the field of the pathological testing has already begun, but in the blood-testing field, support of diagnosis and clinical practices using electronic images is not yet widespread. However, with the application of Telemedicine to blood testing, it is expected that assistance of clinical practices within hospitals and diagnostic support between hospitals will be realized. These trials examine the practical applications of "Telehematology".

WHAT IS EXPECTED OF TELEHEMATOLOGY?

In clinical laboratory testing, evaluation of hemocyte morphology plays an important role in the diagnosis of diseases including those of the blood; but unlike numerical data such as complete blood count (hereinafter called "CBC"), biochemical tests, etc., it has been difficult to report cell morphology to the site of clinical practices as objective data. It is possible to handle hemocyte images viewed through a microscope on a computer by electronically capturing hemocytes on peripheral blood smears and bone marrow smears using CCD cameras, and by filing these images in a database, as well as allowing access via networks, it becomes possible to freely access these images from the database throughout the network. If it becomes possible to refer not only to CBC test data but also to hemocyte morphology from terminals installed at medical service sites such as clinics, hospital wards, etc., clinicians will be able to obtain more complete details of the hemocyte morphology of patients than is available currently.

In addition, in case study meetings, making use of elec-

tronic images from a database, it eliminates the need for time consuming color slide preparation and also allows to freely search, compare, and refer to historical images for cases with recurrent disease. In addition to this, because images are stored electronically, unlike specimen slides or color slides, there is no possibility of color fading or problems with storage. On the other hand, by building up a network environment in which images can be referred to between hospitals, even in sites without specialist doctors or medical technicians, it will become possible to refer to doctors and medical technicians at key hospitals to view the hemocyte images and their diagnosis utilizing these images will become possible. Remote diagnosis support using electronic images and networks could be implemented more easily and quickly than the consultation, etc. which have been traditionally carried out by mailing specimens, and this method is expected to have highly practical applications.

INVESTIGATION AT CENTRAL CLINICAL LABORATORY, KEIO UNIVERSITY HOSPITAL

In our hospital, we are undertaking an investigation of "Telehematology" using the Sysmex LAFIA, Blood Cell Image Filing System (***Fig. 1***). For the purpose of this trail both developing intra-hospital networks and use within the hospital have been investigated. Application of image consultation is also being examined within inter-hospital networks.

Apparatus

The LAFIA system comprises of the LAFIA server and the LAFIA client, and by importing hemocyte images to the LAFIA server, which functions as a database server and Web server, the image database is built up (***Figs. 2 - 4***). The captured images are referred from the LAFIA client and at the same time can be browsed to by accessing the database using a Web browser from terminals connected to the network (***Fig. 5***). Images are imported with a microscope connected to a CCD camera from the LAFIA client. Images acquired by LAFIA provide 640-by-480 image resolution and can be stored either in the BMP or JPEG format. In JPEG format, the image compression ratio can be set at three levels: high, medium, and low, and at the JPEG low level compression setting, about 50,000 images can be stored in the database. When storage capacities are exceeded, images can be backed up on external storage devices and can be referred to as required. In LAFIA, patient attributes as well as CBC, differential blood count, myelograms, and other results can be stored together with images, and it is also possible to directly record comments on images (***Figs. 6 - 7***).

Creation of hemocyte image database (Figs. 2 - 4)

In our hospital, hemocyte images are acquired from bone marrow and peripheral blood smears, and mainly from bone marrow smears in cases with high priority blood disease receiving first consultation, reference cases, etc., and creation of a hemocyte image database has been

Fig. 1 *"LAFIA" blood cell image filing system*

Fig. 2 *Image data list screen*

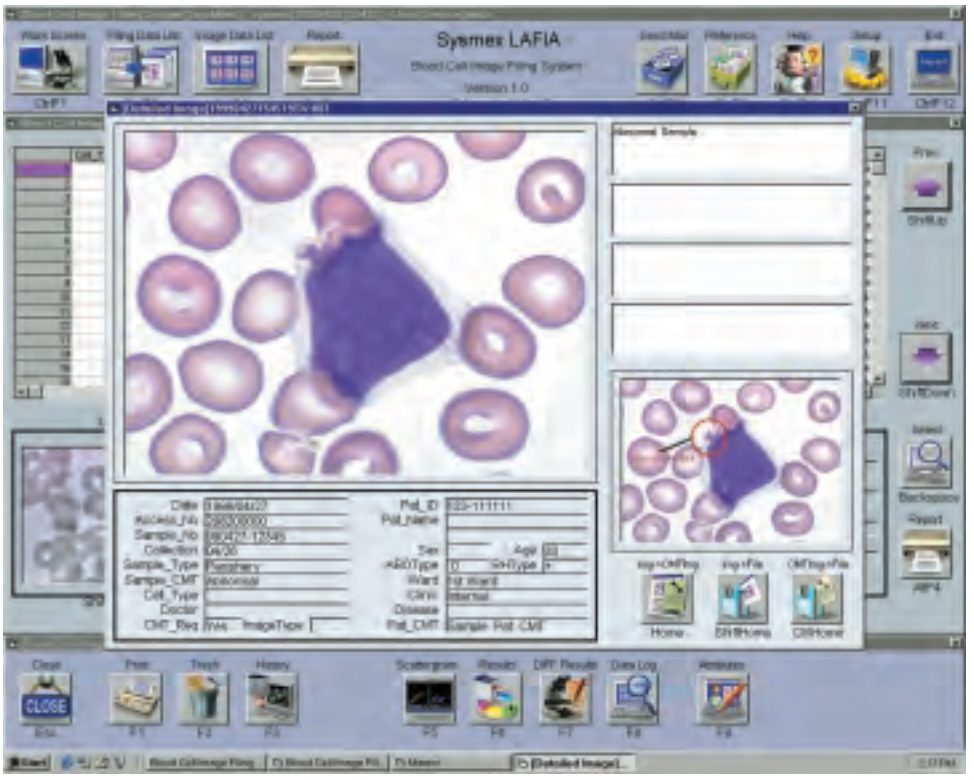

Fig. 3 *Detailed image screen*

Fig. 4 *Reference image screen*

developed. The patient information and test data are stored together with images as required so that consolidated clinical information can be referred from the database. Since the images in the database can be freely searched, required images can be easily accessed for each patient or each disease type. This has enabled easy referencing of blood images and bone marrow images of past episodes, and in the case of recurrences, the cytomorphology at the time of first visit can be compared with recent episodes with greater efficiency than possible before. Images have been imported at the JPEG low-compression setting, and by comparing to an online monitor, image quality has been shown to be very satisfactory, and cell characteristics reproducing the microscope view almost exactly.

Investigation of "Telehematology" using Intra-hospital Networks (Fig. 5)

The LAFIA server is installed and administered in the Hematology Laboratory of the Department of Laboratory Medicine. The LAFIA server is connected to two independent networks installed in the hospital, enabling the use of hemocyte image database throughout the network. Images in the database can be referred from hospital clinics and wards by the connection to medical service network terminals, and are used for referring to test orders and results. In addition, in order to enable use of images by laboratories, conference rooms, etc. where no medical service terminals are installed, intra-hospital networks specialized for the image database have been created and the use of hemocyte images for research and education as well as case studies, etc., has been encouraged. At hematology case study sessions, image conferences using the LAFIA database are carried out, in which a notebook computer and a projector are connected to the research networks from the conference room, and hemocyte images from the LAFIA DB can be accessed allowing cell images of the case to be discussed.

This enables confirmation of bone marrow images of new inpatients or comparison with cell images at the time of first visit in the case of recurrence. As a result, hemocyte images may be evaluated and diagnosis confirmed by a number of people; and compared with preparation of color slides, the time required for importing images is greatly reduced. In addition, bone marrow cell images of new inpatients on the admission day can be presented in real-time.

Investigation of "Telehematology" Image Consultation, in Inter-hospital Networks (Figs. 6-7)

Telehematology and image consultation within inter-hospital networks is expected to have the most beneficial applications. However, for the diagnosis of blood diseases using images, time required for transmitting images would in addition to image quality of the hemocyte image, be a potential barrier and its usefulness is now being investigated using LAFIA.

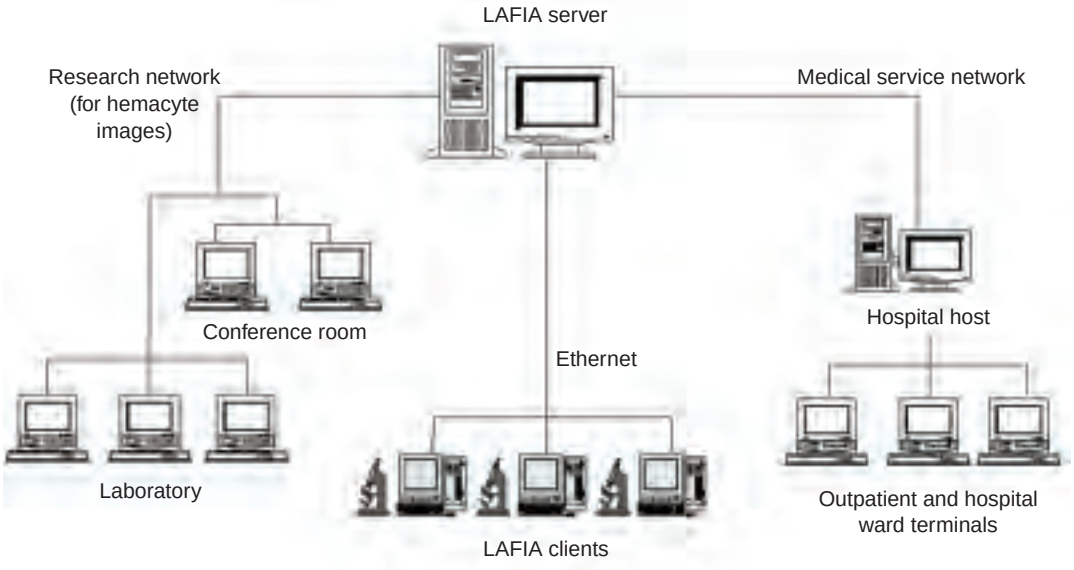

Fig. 5 *Networks in Keio University Hospital*

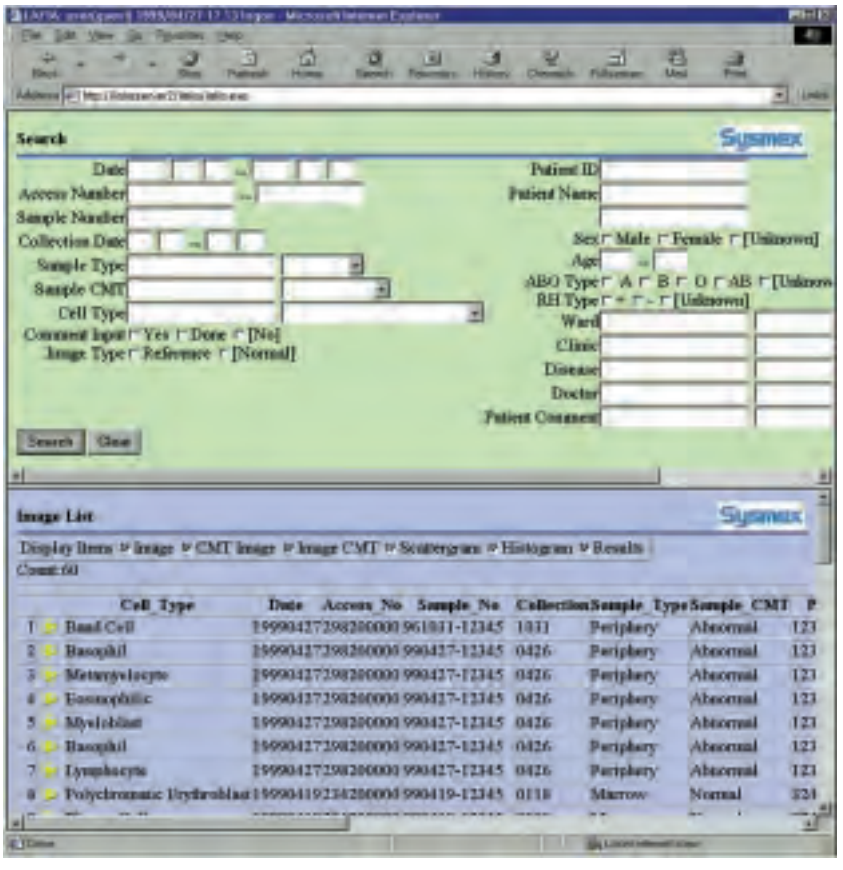

Fig. 6 *Web search screen (listing)*

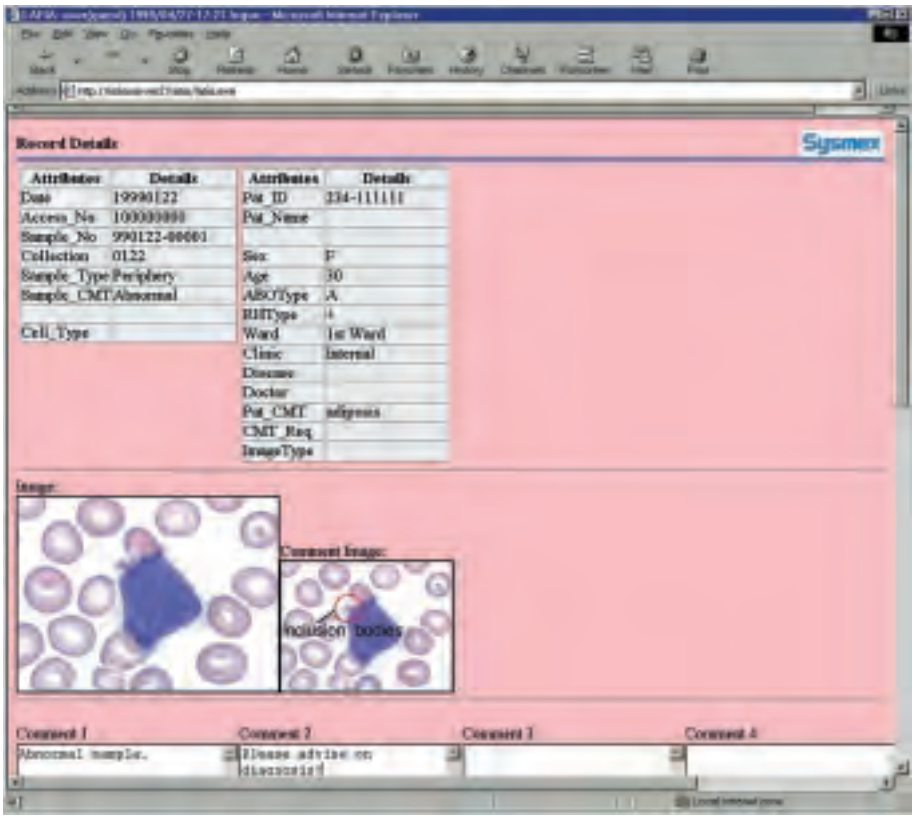

Fig. 7 *Record details screen*

For inter-hospital networks various connections may be considered, but those using existing telephone lines would be the most practical method of inter-hospital networking at present. LAFIA stations between sites can be directly connected using telephone lines, and under such connections, the database can be mutually used. However, in the present investigation, another LAFIA server is provided for consultation, and using general telephone lines and PHS terminals, images are transmitted from relevant institutions and stored, and referring to the images on the consultation LAFIA server, discussion is performed. By this method, only required images can be referred without disclosing the entire image database of each institution, and this method is assumed to be useful from the viewpoint of protection of patient information.

For investigation of consultation applications, considering the time required for importing images, data was imported with the LAFIA setting at JPEG high compression. The images at JPEG low compression are about 300 KB per image, but about 50 KB per image for JPEG high compression. Degradation of image quality by increasing the image compression ratio was a concern, but the comparison between normal and low-compressed images results indicated no significant difference in the image quality.

It was assumed that image inquiry would differ greatly depending on the communication environment, but in the case of communication by analog telephone lines and PHS terminal that we adopted for connection to servers for the recent experiments, about 2 minutes were required to read an image list screen displaying 10 compressed images, and about 25 seconds were required to display magnified images. However, at this inquiry speed, there is no interference with the diagnosis flow even when images are being downloaded while discussions are underway, and this method appeared to be practically satisfactory. Investigations were made with 10 images per case as a guideline, but in actual diagnosis about 15 to 20 images would be required including specially dyed images in addition to low-magnified images and high-magnified images. Consultation trials were carried out by accessing the consultation LAFIA server from the relevant institutions using Web browser, and by phone discussions while referring to images. We have performed investigations using hemocyte images of blood disease cases, such as acute myelogenous leukemia, myelodysplastic syndrome, etc., and in all cases, cytomorphological characteristics could be realized from the hemocyte images and correct diagnosis could be obtained.

MEDICAL SERVICE SUPPORT BY “TELEHEMATOLOGY” (FIG. 8)

By importing image data, hemocyte cells which have not been identifiable with microscopy alone can be accessed and identified from various locations within the institution. In “Telehematology” using intra-hospital networks, findings of hemocyte morphology which have traditionally been utilized in laboratories alone can be accessible at various places in the hospital, and can assist medical services from the laboratory section to the clinical practices.

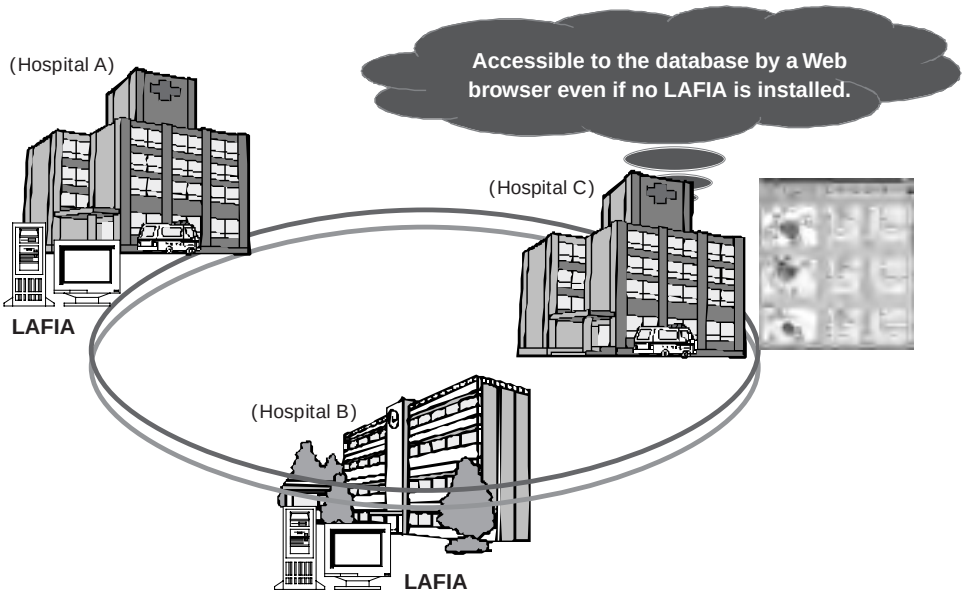

Fig. 8 *LAFIA hospital network*

Also, by creating networks between hospitals, referral of hemocyte images can be realized in hospitals where no medical laboratory technicians specialized in blood or hematologists exist; Consultation can then be done with technicians and hematologists at key hospitals with respect to hemocyte morphology through images by the use of these networks. Conventional consultations have been carried out by mailing specimens, but by "Telehematology", opinions of experts could be more easily obtained in real-time. In addition, since discussions can be made while referring to the same cell images during consultation, opinions can be can directly exchanged. This kind of image transmission could also be applied to education of medical laboratory technicians or diagnostic quality control using images, etc. In inter-hospital "Telehematology" using LAFIA, by directly connecting LAFIAs between institutions, databases can be mutually accessed, and since LAFIA functions as a Web server, it is also possible to reference images by accessing the database from other institutions using any Web browser. With this kind of network environment, because even institutions without LAFIA systems can refer to images on the server, a network connecting many institutions can be created. For each hospitals to access the other sites image database, an agreement concerning protection of patient information needs to be executed, but the practical usefulness of the hemocyte image database including image consultation is expected.

REMOTE DIAGNOSIS BY "TELEHEMATOLOGY" AND ITS LIMITATIONS

As in the case with remote diagnosis by "Telepathology" under investigation in the field of the pathological testing, the remote diagnosis of blood specimens will be an important issue in "Telehematology". The hemocyte images used for "Telehematology" are electronic images imported into a computer by a CCD camera, and presently these images can reproduce microscopic findings very accurately. In LAFIA, images are imported with the use of a 380,000 pixel 3CCD camera, and it is assumed that the imported images have image quality sufficient for diagnosis of blood diseases. The 640-by-480 resolution is not always satisfactory because it is difficult to identify individual cytomorphology when low-magnified view images are referred to, but in the high-magnified images important for blood diagnosis, image quality is such as to enable evaluation of cell characteristics such as nuclear reticular structure, presence of nucleolus, or subtle color tone of cytoplasm, etc., and it is assumed that these images are of sufficiently quality to enable diagnosis. On the other hand, the effects of focusing and light quantity adjustment on images are large, and importing of appropriate images requires certain skills, therefore, image quality is not only concerned with importing of images but also these issues. In particular, in the case of blood diseases where the cell differences caused by staining could sometimes influence the diagnosis, the difference in color tones by monitor characteristic could be a critical

issue. When the apparatus which imported the image differs from the apparatus used for referring the image, there are cases in which color tones differ greatly, and in the case of remote diagnosis, this possibility must be taken into account in assuring accurate diagnosis.
In the case of diagnosis of blood specimens, a large number of cells must be evaluated per specimen, but in the case of remote diagnosis, a sufficient number of cell images are not always utilized because of problems with transmission speed, etc., and improper selection of imported cell images may result in incorrect diagnosis. Therefore, careful evaluation must be performed using the proper visual field and proper number of images. With these problems taken into account, image diagnosis alone is difficult to obtain a definite result, it is necessary in addition, to microscopically examine the specimen.

PROTECTION OF PATIENT INFORMATION

In remote diagnostic support including "Telehematology", protection of patient information disclosed on networks is an important issue. In "Telehematology" in a hospital, with a closed network inaccessible from the outside, patient information associated with image transfer is comparatively safe, but stringent password control must be implemented to prevent any unauthorized third party from accessing patient information. On the other hand, in Telehematology utilizing inter-hospital networks such as image consultation, etc., still more stringent protection of patient information is required. When private lines are installed between hospitals or in cases of direct connection using telephone lines, information can be exchanged comparatively safely, but to utilize the Internet, it is essential to provide security including information encryption, etc. In addition, in exchange of patient information between hospitals, there are many other issues including the need to obtain prior approval of the patient, for which further investigations are required.

CONCLUSION

Attempts at Telehematology have just begun, and there remain many issues to be further investigated before this method is to be accepted for practical use. However, there are a large number of advantages of utilization of hemocyte morphologic information over traditional methods, to assist accurate diagnosis. In particular, the realization of image consultation as remote diagnosis support, is expected to be very beneficial for diagnosis of blood diseases. Further advancement of Telehematology is expected with streamlining of network environments in the future and further investigation of the protection of patient information.

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