TECHNICAL NOTE

GENERAL; PATHOLOGY/BIOLOGY

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Minimally Invasive Postmortem Telebiopsy*

ABSTRACT: For the past 10 years, medical imaging techniques have been increasingly applied to forensic investigations. To obtain histological and toxicological information, tissue and liquid samples are required. In this article, we describe the development of a low-cost, secure, and reliable approach for a telematic add-on for remotely planning biopsies on the Virtobot robotic system. Data sets are encrypted and submitted over the Internet. A plugin for the OsiriX medical image viewer allows for remote planning of needle trajectories that are used for needle placement. The application of teleradiological methods to image-guided biopsy in the forensic setting has the potential to reduce costs and, in conjunction with a mobile computer tomographic scanner, allows for tissue sampling in a mass casualty situation involving nuclear, biological, or chemical agents, in a manner that minimizes the risk to involved staff.

KEYWORDS: forensic science, teleradiology, Virtopsy, biopsy, tissue sampling, mass casualties, nuclear, biological, chemical

Medical imaging is being applied with increasing frequency in forensic documentation (1,2). The Virtopsy approach, presented in 2003 by Thali et al., applies techniques from various fields such as radiology, measurement engineering, and surgical navigation to gather objective, digitally storable data during forensic investigations of the deceased (3–5). As this also requires tissue and liquid samples, we developed techniques for minimally invasive tissue and liquid sampling (6–8) that allow for a precise, target-oriented sampling (9) and minimizes the risk of needle injuries to the operator.

A robotic system for minimally invasive, postmortem biopsy, the so-called Virtobot, was introduced in 2009 (8) (Fig. 1). It allows accurate placement of introducer needles based on computer tomographic (CT) data sets. This system, however, required a radiologist to be present during needle placement to define biopsy targets on the system. Teleradiology systems, where digital radiological data sets are distributed electronically to different geographical locations for evaluation, are used routinely in clinical radiology (10). The advantages of such systems are improved efficiency, after-hours coverage, and access of specialists to remote or underserved sites.

In this article, we present a low-cost approach for a telematic add-on to the Virtobot system, which allows the planning of needle trajectories for tissue and liquid sampling from a remote location. This method combines the advantage of teleradiology with the advantages of minimally invasive, image-guided needle biopsy.

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Materials and Methods

The Virtobot System

The Virtobot system is a multifunctional robotic system that allows for automated surface scanning as well as postmortem biopsy. It is composed of a six-axis industrial robotic arm (Stäubli TX90L; Stäubli, Freienbach, Switzerland) that has been mounted to an external axis, which is aligned with the CT table. It is possible to semi-automatically change the tool the robot is carrying, depending on the application.

For performing biopsies, the Virtobot has been combined with a surgical navigation system. This system consists of an optoelectronic tracking camera, a floor-mountable shield with optoelectronic light emitting diodes (LEDs), a ring of LEDs integrated into the biopsy end-effector, a navigated surgical pointer, and a computer system.

A needle trajectory consists of three parameters: target point, entry point, and the orientation of the biopsy module.

Development Constraints

For developing a telebiopsy system based on the Virtobot, we had to meet several constraints. The system should require as little additional specialized software as possible. At best, any computer system should be ready quickly to allow for planning of needle trajectories. The system should be reliable and have a high data security. As a proof of concept, its implementation should be inexpensive.

Software

For performing a telebiopsy, four software packages are in use. The Virtopsy Control Center guides the user through the workflow of a Virtopsy and integrates the different software packages. The CT scanner (SOMATOM Emotion 6; Siemens AG, Berlin/Munich, Germany) is operated with the SYNGO software (Siemens AG).
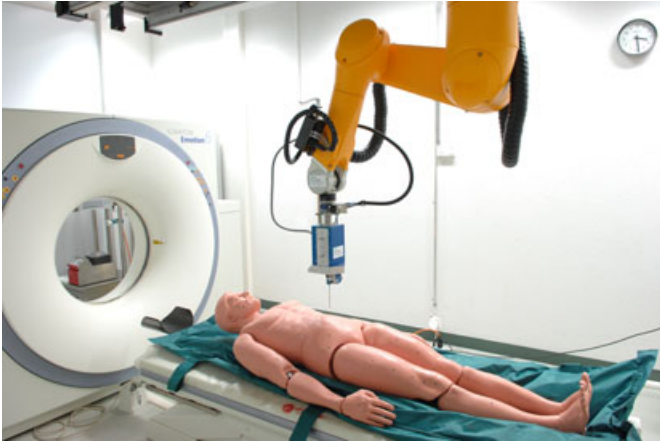
FIG. 1—*Virtobot system with mounted biopsy module.*

Based on the resulting DICOM data sets, as well as positional data from the tracking system, the planning and navigation station allows the planning of needle trajectories and calculates the required position of the robotic end-effector. The last software involved is the open source medical image viewer (OsiriX 3.71; OsiriX Foundation, Geneva, Switzerland), which runs under MacOS, and a custom made plugin, which allows for basic trajectory planning. Unlike full planning software, the plugin is only 86 kb in size and can be easily sent via e-mail.

Telebiopsy—Workflow

A telebiopsy consists of seven steps (Fig. 2).

1. A full-body CT scan is performed and sent to the radiologist using steps 2 and 3. Based on the radiologists report, radiopaque markers are applied around the area of interest. Five markers are usually sufficient. After placing the markers, a CT scan of the area of interest is performed.
2. The CT data set is submitted to the planning and navigation station. There, it is anonymized and encrypted. We use TrueCrypt 7.0a (TrueCrypt Foundation, Henderson, NV) to create a container encrypted with the encryption standards AES-256+ Twofish+Serpent with a combination of password and keyfiles to give maximum data safety (11).
3. The encrypted data set is submitted to the radiologist over the Internet. As it is encrypted, unsecure data transfer methods can be used. Options of transmitting the data are direct connections such as FTP access, communication software such as Skype, or online data storage services such as Dropbox. At the same time, the attached markers and a surgical pointer are used to determine the exact location of the body relative to the tracking camera and therefore the robotic arm. This step is called registration.
4. Meanwhile, the radiologist receives the data and can decrypt it using the keyfile and the password. The data set is then opened in OsiriX. A small plugin (<100 kb) allows the radiologist to define the needle entry and target positions using the OsiriX region of interest tools and export the planned positions into a small textfile.
5. As the textfile only contains coordinates, it is meaningless without the actual CT data set and can be submitted unencrypted, for instance via e-mail.
6. The textfile containing the target and entry coordinates is loaded into the planning and navigation station. The technician now has the option to change the orientation of the robotic head for better LED visibility, if necessary. If the biopsy targets are accessible, the introducer needles are placed by the robot according to the planned data. If the targets are not accessible, the technician can change entry point and orientation of the trajectory or request a replanning.
7. With all introducer needles in place, a second CT scan is performed to document the needle placement. This data set can be submitted to the radiologist as described in steps 2 and 3 for verification. If all needles are placed correctly, the biopsy or liquid sample can be taken, using the introducer needles as a guide.

Discussion

In clinical radiology, teleradiology is in frequent use. According to Ebbert et al. (12), 67% of all radiology practices (in 2003) in the U.S. reported using this method.

The advantages are clear—improved efficiency, 24-h coverage, and easy access to experts. Given the limited number of
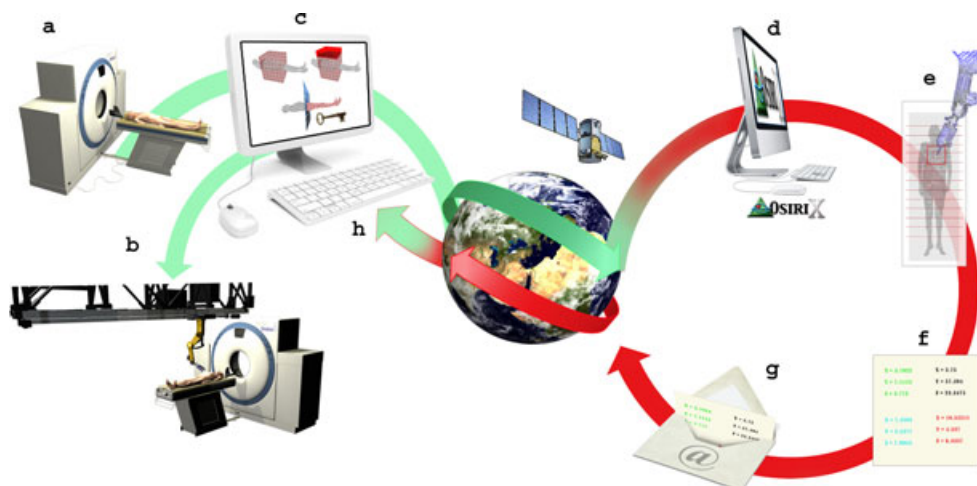

FIG. 2—*Workflow of a telebiopsy. (a) CT scan and submission of data to planning and navigation station. (b) In case of standard robotic biopsy, trajectories are planned and submitted to robot. (c) In case of telebiopsy, data are anonymized, encrypted, and sent over the Internet. (d) Data are decrypted. (e) Trajectories are planned using OsiriX. (f) An OsiriX plugin generated a textfile containing trajectory coordinates. (g) Textfile is sent back via e-mail. (h) Textfile is loaded into the planning and navigation station, which controls the robotic arm.*

subspecialty-trained forensic radiologists and the fact that radiological examinations play a more and more important role in forensics, similar systems could be applied in forensic investigation. One example of such a system has been presented in this report. Using freely available software in conjunction with our Virtobot system, we created a system for planning robotic biopsies from remote locations. So far, this system was used in two cases. Tissue samples were taken from the liver in both cases.

If a robotic system is not available, the presented approach could be adapted to work in conjunction with a navigation system or stereotactic frame.

In 2007, Rutty et al. (13) published the concept of using a mobile CT for disaster response, which can be easily transported to scenes with mass casualties such as the tsunami in South-East Asia in 2004 with *c.* 250,000 victims. In conjunction with a high-speed data connection, such a system could be operated by technicians, while the data evaluation is performed by groups of experts in different parts of the world. This would increase the efficiency and decrease the time necessary for the identification of large groups.

One scenario that would benefit from an approach like this is a mass casualty situation, involving nuclear, biological, or chemical agents. In such cases, where the bodies are contaminated, an additional robotic system would allow for retrieval of tissue and liquid samples without putting the technicians at additional risks. However, the prerequisite for such a fully automated telebiopsy system would be a mobile CT equipped with a Virtobot or similar system. The possibility of planning trajectories from a distant location, as introduced in this work, limits the number of individuals required in the disaster zone.

Future Work and Conclusion

Currently, the system requires manual anonymization, encryption, and data transfer. Future developments of the system include the integration of this functionality into the planning and navigation station as well as the OsiriX plugin. Additionally, the system will be tested over larger distances to completely assess the feasibility. In the long term, we aim to develop a system that allows a completely automated approach, including automated tissue or liquid retrieval.

Acknowledgments

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