Erhöhte Sicherheit bei der robotischen Schädelbasischirurgie durch redundante Navigation und automatische Registrierung

Increased safety in robotic skull base surgery with redundant navigation and automated registration

Jochen Wurm[1], Bohr, C.[1], Dannenmann, T.[2], Nimsky, C.[3], Iro, H.[1], Bumm. K.[1]

[1]Klinik und Poliklink für Hals-Nasen-Ohrenkranke, Universität Erlangen
[2]Institut für Medizinische Physik, Universität Erlangen
[3]Neurochirurgische Klinik, Universität Erlangen

Introduction

After the initial hurdles have been taken and proof of principle work has been completed, safety mechanisms as well as the realization of a feasible clinical setup have become a major issue in robotic surgery today. We present an advanced version of our robotic setup for paranasal sinus surgery that was first introduced in 2003. The system was interconnected with a redundant navigation system for increasing intraoperative safety while performing telemanipulatory as well as fully automated maneuvers.

Methods

In contrast to the previous "all in one" version, we built a modular three component setup (figure 1). The robot is placed on a pedestal and can be immobilized with the operating table by two mechanical arms. An optical camera for the computernavigational control is placed on a mobile tripod. The system control module is connected to both via one cable each.
Basic feature of the computernavigation system is the "CAPPA" station for ENT surgery. The system references by automatically detecting a referencing frame mounted on a non-invasive upper jaw mouthpiece. Software components of both systems, navigation and robotics were combined to one user interface.
Accuracy as well as clinical applicability studies were carried out. The systems operational gross accuracy was tested by maneuvering the robots tooltip, which operates as a

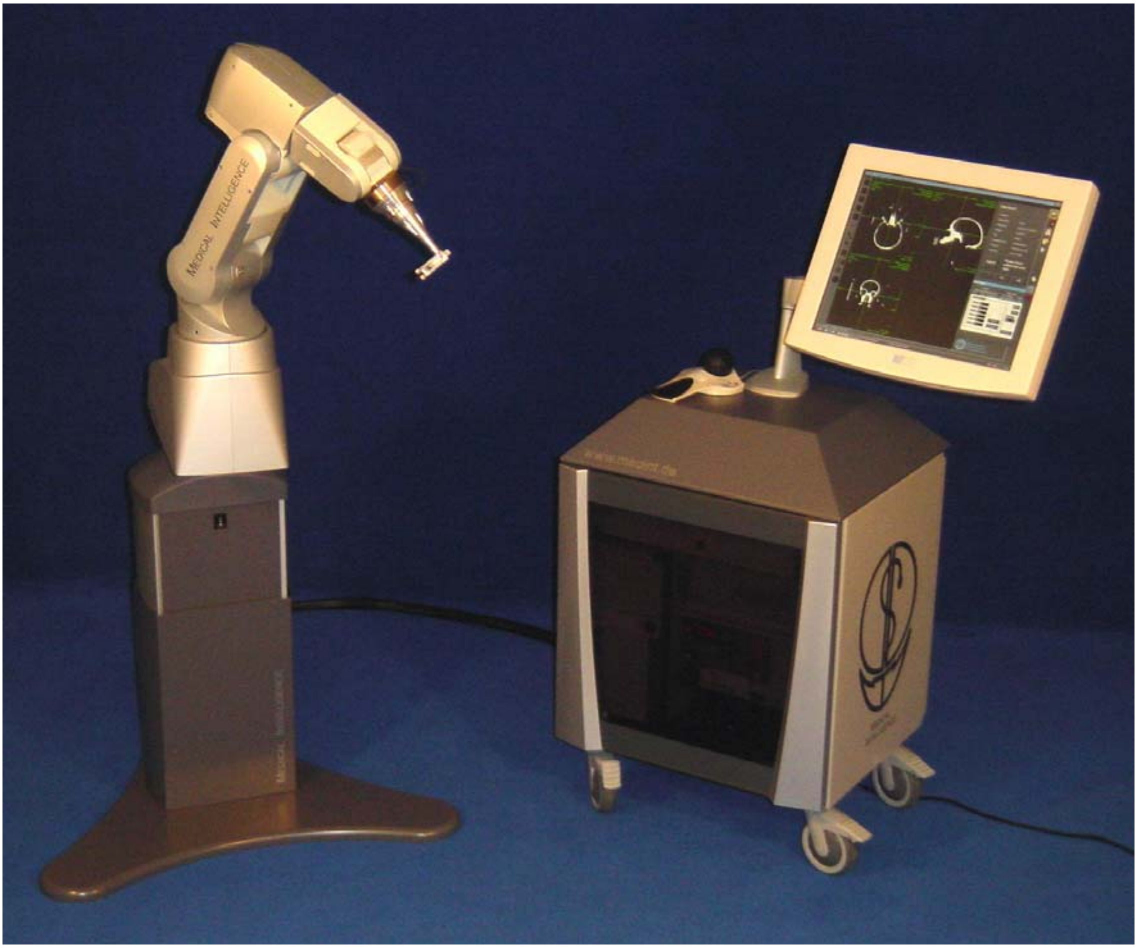
stereotactic pointer, onto CT markers (1mm diameter) placed on the phantom´s head outer skull and bony paranasal sinus walls. Resulting positions were categorized as absolute accuracies and graded as either adequate or inadequate. Obtained absolute accuracies were assessed by measuring distances from the tool tip to the pinpointed marker both on the screen and on the head.
Absolute accuracies were deemed adequate when both distances were equivalent or inadequate with either distance showing an offset of larger than 1mm. Maneuvers were performed either fully automated, or telemanipulatory on cadaveric heads.

Results

A modular setup was designed and was deemed feasible in its size and weight dimensions as well as its maneuverability for application in a routine operating room environment. The camera in combination with the registration frame allows an automated patient referencing. The navigational feedback is integrated in real time in the robots user interface. In case of blocked visibility to the DRF the robot powers down and activates the force torque sensor, thus softening all articulating joints.
In the telemanipulation mode using only navigational feedback without visible control both on the heads surface and in the paranasal sinuses, we found solely inadequate accuracies in pinpointing a specific marker. Accuracies with both navigational control and endoscopic view were found adequate both on the skulls` surface and within the paranasal sinuses. Fully automated procedures were all performed with adequate accuracy on the head´s surface and paranasal sinuses.

Discussion

The challenge was to integrate a redundant computernavigational control system with the robot´s operating system under one control module. This enables the navigational system to actively interfere with the robotic execution if certain safety standards are not met or extravagate during surgery. By using redundant navigation feedback, we were able to add another safety feature, the “loss of control” function, which shuts down any robotic action. However, no increase of the absolute accuracy was observed by adding this feature. We conclude that redundant navigational control does not make the robot more accurate, but it adds a potent safety features to the system.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