Artist's impression of Beijing Jishuitan Hospital buildings

A PIONEER IN MEDICAL ROBOTICS

Feedback from the medical frontline, along with a talented in-house team and collaboration network, has nurtured ROBOTIC INNOVATIONS AT JISHUITAN HOSPITAL IN BEIJING.

Musculoskeletal conditions are a leading contributor to disability, according to a 2019 WHO report. For many orthopaedic diseases, surgery is the main treatment option. Yet, despite the growing demand for minimally invasive procedures, there is a lack of intelligent equipment to aid complex procedures. Driven by this clinical need, technological innovations are a major focus at Beijing Jishuitan Hospital (Jishuitan), which has been a frontrunner in orthopaedics and burns treatment since its establishment in 1956.

"Overcoming biological limitations to achieve precise and stable operations has long been a hurdle for surgeons, impeding the development of orthopaedic surgery," said Wei Tian, Jishuitan's president, and a member of the Chinese Academy of Engineering. "Robotics technology offers solutions, so we started researching and developing orthopaedic robotic technologies in 2002."

Led by Tian, a renowned orthopaedic physician, the hospital was a pioneer in computer-assisted navigation technology, and established a system for intelligent orthopaedic surgery. By building open, shared platforms for technological innovation and research translation, Jishuitan has led numerous collaborations with enterprises and academia for national and local government-funded projects. "Making hospitals the frontline of collaboration, we seek to standardize technologies developed by experts, and make them smarter, and ultimately, better serve patients," Tian said.

Enabling hospital-initiated innovations

Trauma orthopaedic surgery accounts for half of orthopaedic surgeries in China, and is usually complicated, demanding top surgical expertise. To meet the demand for personalized minimally invasive treatment of pelvic fractures and other traumas, Jishuitan's Xinbao Wu, a clinical expert in trauma orthopaedics, is leading the development of robot-assisted hip fracture reduction.

Wu has integrated his experience in fracture reduction and fixation into computer-assisted surgical plans to digitize clinical know-how for robotic intelligence. Starting with skeletal traction, robots are programmed to position screws and wires for keeping bones in place. As incorrectly realigned hip bones delays healing, robots also target precision for procedures of segment repositioning and fixation. Innovative methods for surgical procedures proposed by Wu have contributed to enhanced automation and intelligence of the robot.

Apart from open surgery, Jishuitan's Yajun Liu collaborated with Wenyong Liu's group from Beihang University to explore a new realm for orthopaedic robotics. Shockwave treatment uses pressurized air or electromagnetic pulses to help alleviate and even eliminate acute or chronic pain in bones, tendons or other soft tissues. Designed to increase treatment automation and reduce doctors' workload, Liu's system is comprised of a robotic arm with six degrees of freedom, a customized end-effector for collaboration between surgeon and robot, a personalized trajectory planning module for automatic treatment, a shockwave auto-control unit, and a medicated silicone patch. Its multi-modal sensor units allow for real-time examination of skeletal structures and soft tissues to identify injury or lesions. The system can also automatically adjust the shockwave energy for optimal effect, while ensuring safety. Easy to use, and applicable for a range of conditions, the technology offers potential for orthopaedic treatment at grassroots hospitals.

Building a collaborative network

A clinician-centred model for medicine-engineering-industry collaboration, proposed by Tian, is integral to Jishuitan's success in accelerating clinical translation of robotics research. "Doctors can identify real clinical issues, so the research and design can meet clinical needs," Tian said. "Meanwhile we also need engineering technologies to achieve doctors' ideas, and industrial support to commercialize research results."

The development of TIANJI®Robot, led by Tian, is a good example of such collaborations. As China's first orthopaedic surgical robot product, it is applicable to 13 different bone parts including spine, pelvis and limbs. The robot-assisted navigation allows for high precision at 0.82mm, leading to an internal fixation success rate of 97%. The robot is also easy to operate, reducing operation time by 27%.

Based on its capacity, Tian's team created nine procedures and the world's first guidelines for robotic navigation-assisted orthopaedic surgeries.

"We communicated with engineers and enterprise staff frequently to update the prototype, making sure that the clinical setting and surgeons' operational preferences were considered when designing the product," Tian said, emphasizing the importance of collaboration for the design of TIANJI®Robot.

Also working with TINAVI Medical Technologies, the same company that developed TIANJI®Robot, another Jishuitan team, led by Yixin Zhou, is focusing on a system for total hip arthroplasty with a kinematic-kinetic planning module.

In hip replacement, correct orientation of the acetabular cup, the component placed into the hip socket, is critical. Based on the movement of the spine and pelvis in different postures, like sitting and squatting, the robot calculates an individualized orientation target to reduce risks of impingement, edge-loading and dislocation.

Zhou's team is also working on robots for total or partial knee arthroplasty, which can achieve a personalized surgical goal that restores normal knee kinematics and kinetics based on intraoperative data on joint movement and soft tissue tension.

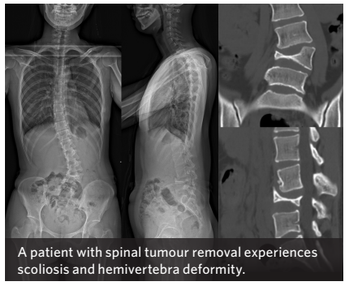
Another example is China's first robot for ultrasound-guided aspiration, co-developed by Jishuitan's Geng Wang, with the Beijing Advanced Innovation Center for Intelligent Robots and Systems, at the Beijing Institute of Technology. It can be used for block anaesthesia, as well as catheter placement for deep veins, and needle biopsy for soft tissue masses. Using the robotic system reduces operation time and risk of complications.

The team has applied for patents for their technologies, and is working with enterprises to push forward the commercialization and clinical launch of the robot.

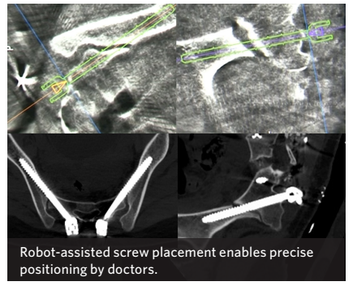
These results have led to clinical applications and numerous national and local government awards, all demonstrating the success of the collaboration model. Its efficiency is fuelled by an established broad network of partners, along with the hospital's improved system for technology transfer, which covers services for identifying clinical needs, connecting with engineering research teams, incubation, and patent application, ensuring smoother and faster transformation of research results.

Looking ahead, Tian expects to further improve the performance of orthopaedic robots. "We will push for greater precision, safety, and manoeuvrability, and enrich their functions to better meet clinical needs," Tian said. "And technically, we will focus on a slimmer design, remote operation, and enhancing machine intelligence through AI, deep learning, and other technologies."

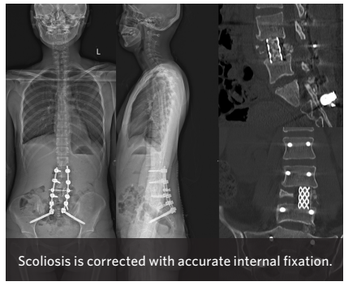
Broader collaboration will continue. ■



A patient with spinal tumour removal experiences scoliosis and hemivertebra deformity.



Robot-assisted screw placement enables precise positioning by doctors.



Scoliosis is corrected with accurate internal fixation.

Professor Wei Tian is using TIANJI®Robot in the operating theatre.

Professor Xinbao Wu is performing a surgery.

TIANJI®Robot

Developmental milestones in medical robotics:

2007
A dedicated research centre for computer-aided surgery research and application started operation.

2010
A medical robotics engineering lab was established.

2016
Beijing Key Laboratory of Orthopaedic Robotics was inaugurated.

2019
The total number of granted patents reached 124, leading to 102.3 million yuan from licensing and patent income.

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