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set to shape the future of medicine.**

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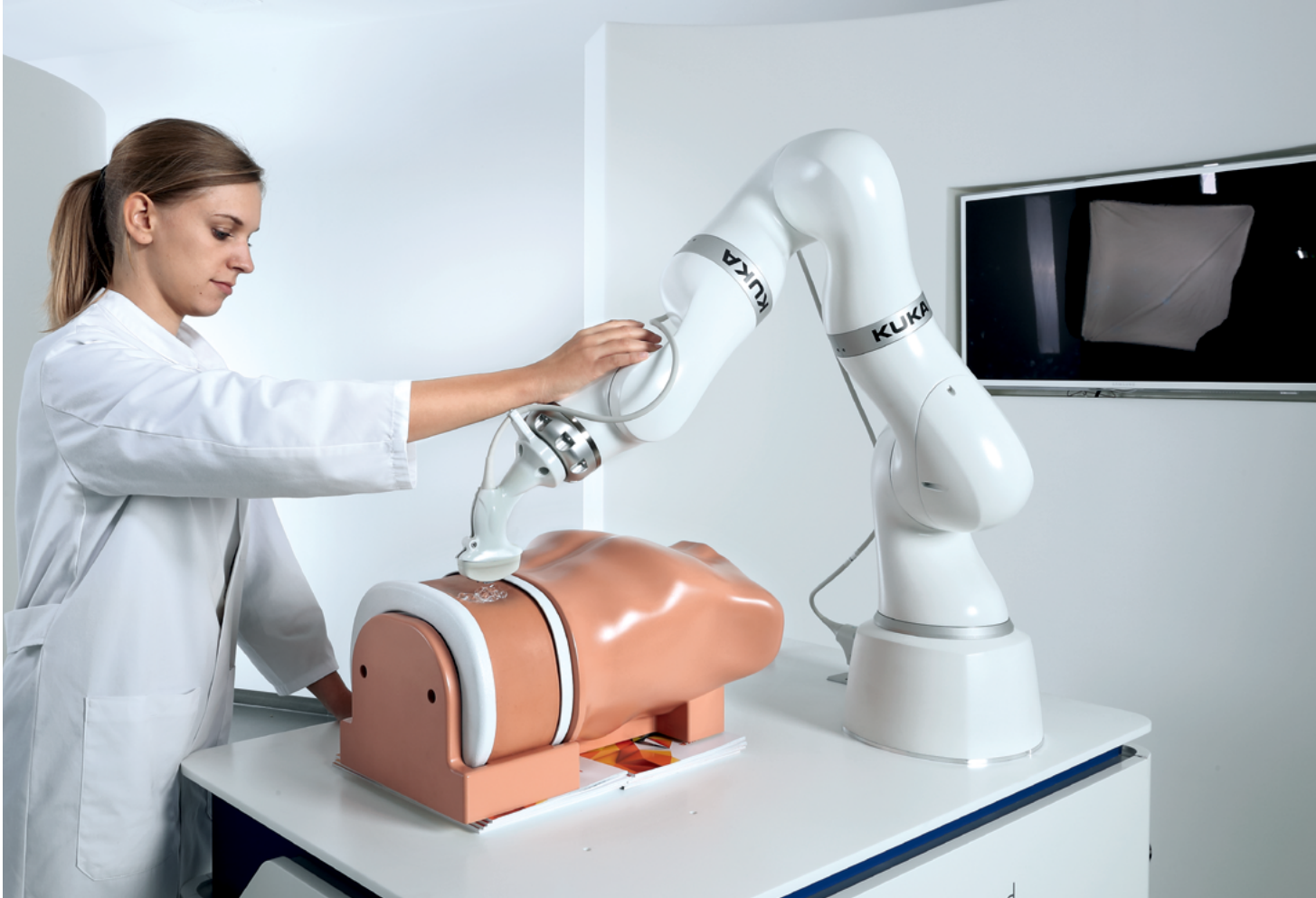
While robots are gaining a greater presence in the world of medicine, they are not newcomers to this field. The innovation and software developments in medtech are driving the industry, but the system's backbones are well-designed, robust robotic systems. They have been providing assistance for patient treatment in healthcare facilities from New York to Berlin and Tokyo for over 30 years. The most well-known system from the "pioneering age" is probably the Da Vinci surgical robot. Yet, despite all this "tradition," the age of medical robotics has only just begun. Sensitive and collaborative robots, in particular, will play a defining role in the future of robotics in medicine.

Are you familiar with Star Wars, Episode V? If so, you will certainly remember how the film ends. In the final lightsaber duel against Darth Vader, Luke Skywalker loses his right hand. He is able to flee and has a perfectly functioning prosthesis transplanted by an autonomously operating robot system. "We are not quite that far yet in the fields of medicine and robotics, but our progress is also not to be underestimated," says Axel Weber, Vice President Medical Robotics at KUKA in Augsburg. Products manufactured by automation specialist KUKA include robotic components for integration into medical products. This is not a recent development. "The first KUKA robot to be used in medical technology was put in to operation in 1999. With it, we supported a radiotherapy system. Back then, the robot held a linear accelerator for the pinpoint irradiation of tumors. These applications are still highly relevant today and are in widespread use," reminisces Axel Weber.

Helpful medical assistants

There are good reasons that robots are used in medical settings, with distinctions being drawn between the three larger fields of application. Robots can be used, for example, to carry large loads, such as linear accelerators or X-ray devices. Other potential applications include processes that require great precision, such as the exact positioning of an instrument. They also involve sequences that last a long time and require consistently high precision, such as surgical operations. Another scenario would be repetitive processes in which a robot performs the same task over a long period. One such example is the early rehabilitation of bedridden patients for whom a predefined therapy is to be achieved.





Ultrasound diagnostics: Sensitive technology and safe human-robot collaboration are the domain of the LBR Med. Thanks to the integrated sensors, it can react to its surroundings both interactively with the physician and via telemanipulation.

KUKA's entry into the world of medical robots began with large industrial robots. "Large robots continue to play an important role as components of medical products," says Axel Weber. The advantages are obvious. Patients benefit from increased safety and precision of the treatment. Clinics improve quality by means of easily reproducible results and can also boost their productivity. "However, collaborative, sensitive robots are becoming increasingly important in applications which the smaller, sensitive robots work hand in hand with physicians and therapists, assisting them with the treatment," affirms Axel Weber referring to potential medical applications being opened to robots due to technological progress. "This type of sensitive, collaborative robotics will enable many further advantages in medical environments in the future, with all sides complementing one another and exploiting their respective strengths. The physician or therapist plans, controls and monitors while the robot performs the tiring and strenuous tasks, as well as those that require particular precision and, above all, sensitivity."

A wide range of applications is becoming possible

These sensitive robots are already providing a glimpse into the future as components of medical products in a variety of applications. A sensitive robot system is being used in

rehabilitation to move the legs of bedridden patients for therapy purposes. In the field of cosmetic surgery, the ARTAS iX, a product of Restoration Robotics, uses a sensitive robot with a special instrument to remove hair from a human head and implant it in bald areas. Another example is MURAB, an EC-funded research project that aims to increase the precision and effectiveness of biopsies in breast cancer diagnosis using a robot-controlled ultrasound scanner to enable more targeted use of expensive MRI scans.

Also approaching market readiness is CARLO®, short for Cold Ablation Robot-guided Laser Osteotome, a medical product from the Swiss startup AOT AG. The objective of this medical product is to radically improve the results of bone surgery by replacing mechanical cutting instruments with noncontact "cold" laser photoablation and robotics. "Following preoperative planning by the physician, the sensitive robot is guided by a navigation system and performs the procedure independently. Besides high precision, CARLO® enables freely defined, curved and functional cutting configurations, which would not be possible with conventional instruments," says Axel Weber, explaining the function and advantages of the system. As a result, the procedure is more precise and less invasive, and generally offers the patient shorter surgery and healing times.

One robot, numerous opportunities

What do all of these application examples have in common? “The sensitive robot integrated into these applications is the LBR Med from KUKA, the German abbreviation for ‘Lightweight robot Medicine,’” explains Axel Weber. The first units were introduced to the market in September of 2017. The base technology for the robot originated in the German Aerospace Center (DLR), where a lightweight, sensitive robot arm was developed for use in space. KUKA adopted the robot as part of a technology transfer and further developed it for industrial operation as the LBR iiwa. “Our medical robotics team modified the LBR iiwa to create the LBR Med,” says Axel Weber, describing the development history of the robot.

What are the advantages of the LBR Med? “It is the only robotic component that has been certified in accordance with the CB Scheme, so our customers can easily integrate it into their medical products,” explains Axel. Since the applications that the robots are integrated into are finished medical products, the systems must always be tested and approved accordingly. There are international standards for this, such as IEC 60601-1 for medical electrical equipment and IEC 62304 for medical device software. One of the most attractive features of our LBR Med robot is that we developed it on the basis of these standards. As previously stated, this makes it the only robotic component that comes with such a certification from an accredited test center for integration into a medical product.”

Furthermore, the LBR Med features integrated sensitivity. This is a major advantage for medical product manufacturers. “In the past, manufacturers who used robots in their products had to additionally develop this sensitivity to use them in the immediate vicinity of patients. That effort has now generally been eliminated,” says Axel Weber. Robots that work on or with humans always require a corresponding safety system. They must either be protected by a special cover or have integrated sensors that detect undesired contact, or they must be equipped with an external system, such as cameras that monitor the robot. “The LBR Med has force-torque sensors installed in all seven axes, providing it with this sensitivity and safety. In the case of even the slightest unplanned contact, it can come to a complete standstill and interrupt its tasks. This sensitivity can also be used for simple, intuitive operation of the system by hand.”

The required tests and documentation for the LBR Med were carried out by the independent inspection and certification institute of the German Association for Electrical, Electronic & Information Technologies (VDE). The final result was a CB test certificate that is supplied with every LBR Med.

Minimally invasive surgery: The highly developed controller enables precise operation with a trocar kinematic system.





Orthopedic surgery: Thanks to its stable design and construction, the LBR Med is suitable for bone surgery. Open-source libraries facilitate the fast development of prototypes and the integration of navigation cameras.

Specialist team for medical robotics

“We are not only the sole robot manufacturer to meet the standards of the medical product manufacturers with the LBR Med, but also the only one with a specialist team for medical robotics,” says Axel Weber proudly. The company has about 40 dedicated employees working in the area around the world. Development, Service and After Sales are controlled from the headquarters in Augsburg. “Worldwide, our customers have incorporated about 1,800 robot systems into their solutions. This makes us one of the most important players in the medical robotics market,” says the Vice President of Medical Robotics.

KUKA produces the robots that medical product manufacturers implement into their solutions. How does this type of collaboration work? “Once the two companies have made contact, we start joint development and product management workshops to discuss the requirements and possibilities and to identify the appropriate robot,” says Axel Weber. Once this has been accomplished, the customer can evaluate the robot and build a prototype of their medical application. KUKA supports the process with robot training courses and a dedicated support team. This goes hand in hand with further joint workshops to support the customer in the development of their product. This also involves the adaptation of the robot to specific requirements of the customer application.

Exciting future

Collaborative robots have a big future in applications that need sensitive robotic systems. Axel Weber predicts a big future for collaborative and sensitive robots in medicine. “They will be used in more and more fields going into the future. The demand in surgical and therapeutic applications will move increasingly towards small, compact, precise and sensitive robots, making the sensitive LBR Med robot a natural fit for them.” Due to a large demographic change, there is also great potential in the areas of rehabilitation and elderly care. “Here, systems that could make life easier for older people are conceivable, such as mobile systems and robot arms that can lift or carry. Or systems for transporting patients or relocating them from one bed to another.”

Axel Weber sees artificial intelligence as important development for enabling improved planning of patient care in the future. He also envisions how it will affect robotics. „Once this technology is mature, the performance of robot systems will greatly increase. This is not an entirely new idea. The first steps took place 20 years ago, but the time was not right for it. Today, the situation has changed, as the technology is on its way to being able to implement these possibilities,” affirms Axel Weber.

These advances are great, but the use of a robot system remains entirely dependent on its acceptance by physicians and patients. As far as the former are concerned, Weber sees general acceptance, provided the physician retains overall control. “It is the doctor who, ultimately, decides what the robot does and who has control over the entire medical application. Young doctors, in particular, demonstrate great willingness to work with such systems,” he explains. With regard to patients, however, more educational work is required. “Acceptance here is heavily dependent on the specific application,” says Weber. “It is easier to let a robot guide the motion of an arm or leg during rehabilitation than to submit to an operation conducted by the robot.” The challenge today, therefore, requires a delicate transition and combination of tradition and modernity to ease the minds of those new to these exciting applications.

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About KUKA AG

KUKA is a global automation corporation with sales of around EUR 3.2 billion and around 14,200 employees. As a leading global supplier of intelligent automation solutions KUKA offers its customers everything from a single source: from robots and cells to fully automated systems and their networking in markets such as automotive, electronics, general industry, consumer goods, e-commerce/retail and healthcare. The KUKA Group is headquartered in Augsburg, Germany. (31.12.2018)

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