Medical Applications for Micromachines Part 3

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The Quest for Minimally-Invasive Technologies and the Development of Micromachine Operating Systems

Today, we would be correct in saying that medical-use micromachines are currently in existence. Furthermore, efforts towards the implementation of minimally-invasive practices are currently taking shape in all fields of medicine, and in terms of medical applications for micromachines, these efforts are opening up a wide range of possible uses. When providing treatment as part of medical care, there is no alternative but to act in a way which is invasive to living bodies, and accordingly, it is often considered that the necessary invasive actions should be carried in full, whereas non-required invasive actions should be limited to a minimum. As a result, the number of invasive surgical operations will become fewer.

Around the same time as the Micromachine Project began, minimally-invasive surgery in which a laparoscope was used to perform remote operations was also started, thus realizing at last a tangible revolution in medical operation practices. The keyword in the achievement of this revolution was "miniaturization." In Japan, however, medicine in the same field has failed to reflect this fundamental transformation in operation practices. One of the reasons for this failure lies in the fact that the majority of medical appliances and tools were still imported from overseas; consequently, no domestic companies or corporations were capable of taking on the associated development work. In addition, whether considering the actual operating theatre or the industry in general, this field was hindered by a lack of appreciation and understanding of micromachines and the associated technologies. Nevertheless, the reason for this insufficiency is a simple one: in terms of device-usage methods, there was very little grasp of those mechanical systems which relied on manual dexterity and skill. Specifically, it was simply considered that such devices merely transformed operations which had traditionally been carried out by hand in such a way that they were now performed remotely through a narrow operating channel.

Medical-technology developers in other countries, however, did not share this opinion. Rather, it was felt that in this field in particular, surgical technologies should be re-established in the form of mechanical medical systems. Furthermore, in order that all surgical operations could be re-designed for minimally-invasive systems, there was a desire to determine which sections of living bodies could be adopted as targets for this approach; to determine in which way physical quantities could be measured; to determine how monitoring and observation would be carried out; and to determine the best possible operation methods. In terms of operations carried out via a small trocar, it would be necessary to configure a system for the measurement and control of living bodies using micromachines. In 1999, merely ten years since the first cholecystectomy using a laparoscope, the FDA approved two practical, remote-robot operation systems-namely, Zeus from Computer Motor and Da Vinci from Intuitive Surgical. Furthermore, simultaneous to the start of a wide range of minimally-intrusive operation practices in the US, Canada, and Europe, development also began on system development for coronary-artery bypass operations-a field of operations for which, although there is considerable demand, cases for practical implementation are few and considerable difficulties are felt to exist with regard to the implementation of remote-operation practices. Graft bypass operations on coronary arteries performed without an artificial heart and during which the patient's heart is still beating constitute anastomosis (or pump-off) procedures. The implementation of small micro hands which can also be fitted to beating hearts for arterial anastomosis, in combination with motion scaling of the movements of surgeons' hands, has led to the birth of a remote procedure for this type of operation. In this field, however, there is no classification between orthopedics and internal surgery: rather, the specific method of treatment of the disease or sickness in question is taken into consideration, and action is then taken by integrated medical teams using both robot operation systems and also systems for the planning and implementation of operations which use combined data from medical MRI, x-rays, and CT image devices.

With regard to the technical elements of a micromachine system for inclusion in this type of medical-operation device, a drive method will be necessary to generate a suitable level of torque for the required operations, and it will also be necessary to provide materials which are not harmful to living bodies. Furthermore, a requirement for re-evaluation of the design of these machines may arise based on information relating to viscosity, blood coagulation, and the formation of bubbles when working with liquids; based on information relating to sterilization, antibacterial agents, and other similar issues; and also based on a wide range of restriction conditions determined using said information. It is important to remember that the majority of systems now being put to successful use integrate these principles with combined, high-level medical expertise and knowledge of how to avoid the corresponding problems, and also with unique, industrial technologies.

Medical Micromachines and Gene Therapy

Many now wonder how medical micromachines may be used in terms of gene therapy-the mainstay of post-genome medical technologies. We can all envisage a medical-care environment in the near future where practical treatment will involve the determination of an individual's genes, the identification of any unique abnormalities in these genes, and the implementation of genetic methods precisely matched to said individual. However, it is currently possible only to identify specific disease genes, to load a virus or some other vector with the required genes, and to relay the corresponding genetic information to the entire body. Even if micro and nano-achining could be used to successfully create a DNA chip, genetic therapy will remain an unattainable dream without development of the necessary medical methods; accordingly, the limits of development in this field will restrict our ability to create tools for medical therapy.A post-genome era where all genetic information is fully understood and where the corresponding approach to development is clearly defined may arrive sooner than we think. And although it will then be necessary to identify the tissue or cells where the sickness is occurring, and to implement genetic operations only for that section, no effort is currently being made towards these goals. The reason: micromachine engineers are not present at this type of medical operation.

Even in terms of the localized application of drugs, no all-purpose technology currently exists, and as previously mentioned, it is now widely appreciated that the consolidation of data using future medical-imaging devices will allow the remote insertion of tiny injection catheters into organs, tissue, and cells. Accordingly, there is now a pressing need for the development, not of non-invasive, but of minimally-invasive technologies for the transmission of DNA or medicines to those specific areas where they are needed. For this reason, exciting possibilities are now offered by developments such as Georgia Tech's injection device-a device which employs countless micron-level needles in an area of several tens of microns square. In the near future, we may see a wide range of practical applications for minute catheters being conceptualized and refined in the operating theatre and other locations where medical techniques are implemented; furthermore, such developments would make today's cardio-surgery technologies seem similarly backward as those of a mere twenty years ago, when PTCA and EP catheters used for myocardial infarctions were not yet available. We need to appreciate the degree to which medical treatment will be changed by the arrival of methods which will allow specific locations to be targeted and operated upon in a mechanical fashion. We must appreciate also that these new methods and technologies were originally realized in the operating theatre and other similar locations.

When we view the current situation as described above, the fundamental technologies for the application of micromachines and nano-engineering to medical treatment can be considered as being already in existence. In order that a leading position may be achieved in this industry, it will be crucial for engineers with vision to be present in the operating theatre and other similar locations where medicine is practiced. Today, more than ever before, there is a pressing need for engineers to introduce into these environments all micro and nano-machining technologies which may be put to practical use.