Wired Patients: Implantable Microchips and Biosensors in Patient Care

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After decades of specialization within the sciences, the development and application of implantable microchips and biosensors are now being made possible by a growing convergence among seemingly disparate scientific disciplines including, among others, biology, informatics, chemistry, and engineering.[1] This convergence of diverse scientific disciplines is the basis for the creation of new technologies that will have significant medical potential. As of today, implantable microchips and biosensors are being used as mental prostheses to compensate for a loss of normal function, to remotely monitor patients' vital signs, to control the delivery of medications, and to communicate with geographically distant healthcare professionals and the outside environment.

But, to fully appreciate the significance of implantable microchips and biosensors, it is important to understand that their development and use are situated within larger demographic, economic, and technologic developments, which are also converging to intensify creation of new automated and self-care technologies. These demographic, economic, and technologic developments are the growth of an aging population, society's need to control skyrocketing healthcare costs, and the formation of a comprehensive, global telecommunications network.

When understood in light of this broader context, what are some of the most likely and desirable healthcare consequences of implantable microchips and biosensors? First, microchips and biosensors are likely to support independent living and facilitate continuum of care. In doing so, these devices are likely to help move healthcare delivery from institutional settings to noninstitutional settings such as the home, giving patients more autonomy and a greater role in managing their own healthcare. Second, increased use of microchips and biosensors is likely to make healthcare more proactive and preventative rather than reactive and episodic.

What the above likely outcomes have in common is that, as information and communication technologies are integrated into the human body, the human body itself is more fully integrated into a vast, external information and telecommunications environment that includes, for example, the Internet, electronic databases, and global positioning satellites. Therefore, we should not lose sight of the fact that, as we transform the human body internally with microchips and biosensors, we also transform externally how individuals interact and live in the world. As I hope to show in the remainder of this paper, this transformation is the most immediate and likely consequence of implantable microchips and biosensors for patients and healthcare professionals.[2]

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However, before looking in depth at the issues discussed above, it will be helpful to look first at some of the ways in which implantable or subdermal microchips and biosensors are currently being used and how much of their utility depends on being linked with a larger external information and communication network.

Current Trends in Implantable Microchips and Biosensors

There are a growing number of very specific medical applications for implantable microchips and biosensors, but there are at least three broad functions performed by these medical devices: (1) prosthetic, (2) monitoring, and (3) enhancement.[3] In what follows, I identify and discuss specific applications of implantable microchips and biosensors that are illustrative, but not exhaustive, of the aforementioned functions.

Prosthetic Applications

Although still exotic, neurotrophic brain implants, electrodes that are surgically inserted into the motor cortex of the brain, were first implanted in a human in 1998 and used as mental prostheses to compensate for a loss of normal function in persons unable to speak, for example, because of stroke, spinal cord injuries, or amyotrophic lateral sclerosis.[4] Neurotrophic brain implants are now becoming more commonplace. As recently as 2004, the Food and Drug Administration gave approval to begin systematic clinical trails to implant microchips in the brains of paralyzed patients.[5]

How does a neurotrophic brain implant work? Once the electrode is implanted into the motor cortex of the patient's brain, neurons in the brain transmit electrical signals to the electrode that, in turn, transmits the same signals to a receiver placed on the patient's scalp. These recorded signals are connected to a computer and are used as a substitute cursor or mouse. As patients learn to control the strength and pattern of electrical impulses being produced in the brain, they are able to direct the cursor to a specific point on the computer as they wish. In doing so, patients are able to communicate and can even send e-mail.

Implanting an electrode/biosensor in a person's brain is an amazing medical and scientific accomplishment. It must, however, be pointed out that the success of patient communication in this particular example depends on the existence of an external and established telecommunications infrastructure. That is, without phone lines, computers, the Internet, e-mail, and simple electrical power, a neurotrophic brain implant would be useless and not worth implanting in the first place.

Monitoring Applications

In addition to prosthetic applications that compensate for the loss of normal function, subdermal microchips and biosensors are also being used to monitor human organs. For example, Medtronic Inc., the first company to develop and market implantable heart monitors in 1997, now has implants so small that they can be inserted inside the heart itself to detect atrial fibrillation and to monitor blood pressure and heart rate.[6] For cardiac patients, these miniaturized implants are a significant improvement over the bulky, external electrocardiogram monitors they previously wore.

Another important feature of an implantable, cardiac biosensor is its capacity to be linked to a sophisticated Internet-based monitoring network that allows patients to transmit device and physiologic data to their clinicians without having to leave their homes. Patients do this by holding a small, computer-shaped mouse antenna over their implants, which then sends the collected data to clinicians over standard phone lines. Clinicians can remotely monitor the condition of patients by logging into a secure clinician Web site. In some locations, clinicians can access patient data by means of a handheld computer or personal digital assistant (PDA).[7] Patients also have access to a secure patient Web site where they can obtain health-related information and personalized device data.

What are some of the benefits that stem from the use of Internet-based cardiac biosensors? First, as mentioned above, patients can provide physiologic and device data to their clinicians from the convenience of their homes that previously required an office visit. Second, because these devices can provide up-to-the-minute monitoring, patients may gain greater peace of mind, which could reduce, if not eliminate, unwarranted emergency room and office visits. Finally, because clinicians can obtain real-time physiologic data about their patients, clinicians can be more proactive and less reactive in the care of their patients. Consequently, patients can receive better informed treatments, which, in turn, are likely to result in better health outcomes for patients and reduced healthcare expenditures.[8]

As with the prosthetic application discussed above, the realization of the full benefit of a cardiac biosensor depends on the existence of a sophisticated information and telecommunications infrastructure that can itself record, store, and transmit the physiologic data monitored by the implanted biosensor.

Enhancement Applications

The third application of implantable microchips and biosensors deals with the enhancement of human function, for example, the extension of our senses beyond the immediate environment, improvement in memory and physical strength, or the general augmentation of our abilities to perform various tasks. Like prosthetic and monitoring applications, many of the current enhancement applications of implantable microchips and biosensors depend on the larger telecommunications infrastructure.

For many, enhancement of human function brings to mind sci-fi images of cyborgs with superior physical and mental powers. But we don't have to imagine some possible future to see how human function can be enhanced with microchips and biosensors. In fact, less "sexy" human enhancements for augmenting our normal functions are already in use. For example, implantable microchips, in conjunction with global positioning satellites (GPS), are currently being used to track pets. As a telescope extends our ability to see long distances, this particular application of an implantable microchip increases our ability to "see" where our pets are. In doing so, the use of implantable microchips in pets enhances normal human functioning and abilities. There is, of course, a monitoring aspect, but the primary aim of implanting a microchip in a pet is not to monitor and then transmit its physiologic data; rather, it is to enhance our ability to find a lost pet.

Although in the very early stages of development, programs to enhance human function by implanting microchips in humans have begun to emerge. First, as with pets and GPS navigation systems found in many automobiles, some groups are advocating that microchips be implanted in children and the elderly as a way to make it easier to track and to locate lost or abducted children.[9] Second, companies, such as Applied Digital Solutions, have developed an implantable microchip, called the Verichip, that holds personal data, such as medical information, and can be used to identify persons, making sure that only those who have legitimate access to computers and secure sites can gain access.[10] Third, in the not too distant future, a total integration of the human body and various information and communication technologies may be possible, for example, wireless, subdermal phone and e-mail transmitters that are linked directly to the human brain.

Whether it be a prosthetic, monitoring, or enhancement application, what makes microchips and biosensors useful is not simply their implantation into the human body; rather, it is that their implantation into the human body further integrates the human body into an external information and telecommunications environment. In doing so, we alter our sense of self, gain greater control over our environments, and transform how we interact with each other. With that said, I don't mean to suggest that other medical technologies such as pacemakers, which are routinely implanted into the human body, do not have an effect on one's sense of self. In fact, I would argue that any integration into the natural human body of what is artificial would have consequences for how persons think of themselves and live in the world (e.g., wearing a pair of glasses). The point is that the real power of implantable microchips to alter one's sense of self and relations to the world depends on connections with various external information and telecommunication technologies. As I discuss subsequently, these changes brought about by implantable microchips and biosensors will have significant implications for patient care.

Likely and Desirable Future Trends

At the beginning of this paper, I identified two likely and desirable future trends in healthcare associated with implantable microchips and biosensors. These trends are (1) improvement in the continuum of care and greater movement of healthcare delivery from institutional settings to noninstitutional settings and (2) a more proactive and less reactive healthcare system.

Improving Independent Living and Continuum of Care

First, how will implantable microchips and biosensors likely improve the continuum of patient care? The general answer is that these technologies will better enable the integration of the patient's body with its immediate environment and the larger community, in particular, the healthcare community. Because implantable microchips and biosensors, like many other kinds of information and communication technologies, are interactive, they can help facilitate damaged or less than optimal person–environment interactions that are due to illness or environmental barriers (e.g., lack of transportation). The traditional view in medicine, however, has been to view the purpose of technology as a way to fix persons, not environments. The problem with this view is that it construes persons as being distinct from their environments and overlooks the essential issue of person–environment interaction. As communication technologies and medical implants become more commonplace in the provision of medical services, this traditional view will and should continue to dissipate.

As implantable microchips and biosensors more fully integrate patient bodies with their environments, continuum of care will be facilitated, and patient care will increasingly migrate from institutional to noninstitutional settings such as the home. In addition, implantable microchips and biosensors will be linked to more powerful and sophisticated sensors that allow for the construction of "smart homes" and the creation of almost seamless person–environment interactions. Home-based sensors in concert with implantable microchips and biosensors will exhibit a collective, synergistic intelligence that not only monitors, stores, and transmits biometric data to healthcare professionals, but also allows, for example, elderly or disabled patients to more easily regulate their home environments by controlling lights, temperature, and appliances.[11] By giving patients more control over their environments, implantable microchips and biosensors have the capacity to enhance the autonomy and well-being of patients.[12]

Creating a Proactive System of Healthcare

The model of healthcare delivery utilized today in emergency medicine is reactive and episodic, not proactive and preventative. As such, it is expensive and does a poor job of detecting medical conditions and responding to medical emergencies. Consequently, the present model of healthcare delivery in emergency medicine is less likely to maximize both the quality of patient care and patient health outcomes.[13]

In conjunction with external information and communication technologies, how might implantable microchips and biosensors help us transition from a reactive to a preventative healthcare system? In answering this question, take, for example, the implantable cardiac biosensors discussed earlier that allow for the continuous real-time monitoring and transmission of a patient's cardiac functions. These subdermal biosensors can be coupled with desktop telehealth units and the Internet and include intelligent software/hardware modules that can detect an emergency event that, in turn, can automatically alert an emergency call center.

Unlike a reactive and episodic approach that responds after an emergency cardiac event is in progress, an automated system is preventative. That is, implantable cardiac biosensors when linked with external information and communications technology can detect a cardiac event at its earliest stages and before the patient himself knows what is happening. In doing so, not only are opportunities to prevent serious patient harm or death increased, the costs of treating and managing cardiac patients is likely to decrease. In concrete terms, a proactive healthcare system that can prevent emergencies is a healthcare system that is more likely to be more efficient and lead to better health outcomes for patients.

In addition, as many of the routine tasks and functions that constitute the roles of healthcare professionals are taken over and performed automatically by implants (e.g., nurses measuring patient glucose levels and heart rate), the roles of healthcare professionals will be redefined in a way that allows them opportunities to practice preventative medicine. For example, rather than spending their time and energy collecting patient physiologic data, they will be able to focus more on analyzing patient data, assessing patient health, and developing treatment strategies.

Again, it must be emphasized that subdermal biosensors and microchips alone cannot improve the continuum of care or make our healthcare system proactive rather than reactive. As stated previously, the real power of implantable microchips and biosensors is not so much in how they change the interior of a patient's body, but in how they more efficiently and more broadly allow us to change the way patients and healthcare professionals control and adapt to their environments by means of information and telecommunications technology.

Concerns about Implantable Microchips and Biosensors

The use of implantable computer chips and biosensors is likely to have some very real benefits for patients and for our healthcare system in general. But the use of these devices also raises a number of questions about the quality of care implanted patients will receive. Two particular concerns are device usability and reliability and the potentially negative impact of these devices on provider–patient relationships.

Usability and Reliability

In the broad area of human factors, there remain significant knowledge gaps in our understanding of the usability and reliability of implantable microchips and biosensors. It is important that these knowledge gaps be adequately addressed, as the usability and reliability of these devices will have profound implications for the quality of care patients will receive.[14]

What is needed to fill these knowledge gaps? First, more research in general on technology dependency and the effects of that dependency are required. In the case of microchips and biosensors, we need to understand better, for example, how patients who have a loss of normal function will come to depend not only physically but also emotionally and psychologically on these devices. In gaining a more thorough understanding of the dependencies that patients will likely come to have on their implants, we are more likely to view implanted patients as bio-psycho-social creatures, not just bodies with new gizmos.[15] This, in turn, will help to guarantee that patients receive the highest quality medical care as well as the best medical technology.

Second, we need methods for the testing and debugging of prototypical implants and biosensors in simulated and real environments before these devices are used on a wide scale by the healthcare industry. This means that these devices will need to be tested in the homes and workplaces of patients, not just in the laboratory.[16] Moreover, information and communication technologies, such as standard telephone lines and the Internet, on which some implantable microchips and biosensors will rely will also require testing for reliability and usability, as well as security. Until we have a better understanding of the usability and reliability of implantable microchips and biosensors, especially when they are integrated into a larger telecommunications network, the quality of care that implanted patients receive will remain in question.

Provider–Patient Relationships

Worries about the impact of medical technology on provider–patient relationships and patient care are not new, nor only the result of high-tech medical devices. Many physicians, for example, initially rejected the stethoscope because they believed that the distance it created between them and their patients would undermine the quality of patient care.[17] For these physicians, good medical practice demanded they have direct physical contact with their patients, whether it be a hand on a patient's fevered brow or an ear on his congested chest.

Today, similar worries and questions abound over the use of implantable microchips and biosensors. Will implantable computer chips and biosensors lead to more or less involvement with patients by healthcare providers? Will greater self-care be required of patients who are fitted with implantable computer chips and biosensors? Will these technologies along with increases in electronically mediated interactions impede the development of empathy and compassion between patients and healthcare providers? In more general terms, is the art of healthcare being swallowed up by the science of healthcare, which is a proclivity for technological fixes rather than personal, human engagement?[18]

In addition to the above concerns, one long-held duty that is central to the provider–patient relationship and likely to be altered by the use of implantable microchips and biosensors is the provider's duty to maintain patient confidentiality. The duty to maintain patient confidences has roots that stem from the Hippocratic tradition.[19] The duty of confidentiality is significant because it allows patients to divulge physical and psychological information about themselves with the confidence of knowing their revelations, sometimes embarrassing and socially stigmatizing, will not be shared with others. In sharing personal information, patients are able to provide healthcare professionals with the information necessary for making accurate diagnoses and for prescribing appropriate and effective treatments.

But the duty to maintain patient confidentiality is likely to become more difficult, if not impossible, for healthcare professionals when patient data is being automatically monitored and collected by implantable microchips and biosensors and automatically transmitted over airwaves and phones lines by intelligent software agents.[20] In such a healthcare environment, ought it to be the responsibility of healthcare professionals to guarantee the security of the unsecured phone lines and wireless devices that implantable microchips and biosensors will use to transmit and to store patient data? Before answering this question, however, we need to ask and answer a more basic question: Are healthcare professionals who use these devices able to give such guarantees?[21]

As it stands, the security of standard phone lines, much of the Internet, and wireless transmissions is not within the power of individual healthcare professionals. The overall security of our telecommunications infrastructure involves, for example, federal and state governments, encryption technologies, and hospital policies about who can access patient information. Maintaining the security and confidentiality of patient data in modern medicine is increasingly becoming a systemic task that no one healthcare professional can achieve for his own patients. The expanded use of implantable microchips and biosensors will only make this task more difficult. Hence, it may be misguided to impose a duty of confidentiality on healthcare professionals when it is not within their power to do so. If I am correct on this point, the use of implantable microchips and biosensors, in conjunction with telecommunication technologies, will contribute further to changing what is an ethical cornerstone of provider–patient relationships: the duty to maintain the confidentiality of their patients. In the end, augmented use of implantable microchips and biosensors is very likely to make the protection of patient confidences less of a duty for individual providers and more of a duty for healthcare institutions and government.

Conclusion

My goal in this paper has been to identify and examine some of the ethical and social issues associated with the use of implantable microchips and biosensors in patient care. I provided a taxonomy of three broad functions performed by these devices—prosthetic, monitoring, and enhancement—and explored two likely and desirable consequences of these devices for patients and our healthcare system, the first, that microchips and biosensors are likely to support independent living and facilitate continuum of care; the second, that increased use of these devices is likely to make healthcare professionals and the healthcare system more proactive and preventative, rather than reactive and episodic.

I also looked at some of the concerns about the quality of care that implanted patients will receive. First, I discussed that before these devices are adopted for use on a wide scale more human factors research is necessary. Second, we need to recognize that implants, especially when linked with other kinds of information and communication technologies, could have a deleterious impact on traditional provider–patient relationships. In particular, the use of these devices could make a healthcare professional's duty of confidentiality harder to fulfill and thereby further alter what many consider to be the ethical bedrock of provider–patient relationships.

In closing, I want to reemphasize that the real power of today's implantable microchips and biosensors to transform patient care, whether for better or worse, is not simply their implantation into the human body. Rather, the real power and significance of these devices is their capacity to "wire" patients to a vast, external information and telecommunications network. That is, as these devices are integrated into the human body, the human body itself is more fully integrated into its various environments. Hence, by transforming the human body internally, we also transform externally how individuals interact and live in the world.

Notes

1. National Science Foundation and Department of Commerce. *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science*. Arlington, Virginia: NSF/DOC; 2002.
2. The primary aim of this paper is to identify present and near-future uses (10–15 years) of implantable microchips and biosensors and to examine their implications for patient care. This, of course, does not mean that there are not other important philosophical and metaphysical questions or long-term consequences surrounding the use of implantable microchips and biosensors, for example, nanotechnology, transhumanism, and the creation of self-replicating cybernetic organisms. For an interesting discussion of these topics, see Hooks CC. Cybernetics and nanotechnology. In: *Cutting-Edge Bioethics: A Christian Exploration of Technologies and Trends*, Grand Rapids, MI: W.B. Eerdams; 2002.
3. This taxonomy is not the only possible taxonomy, as some microchips and biosensors have multiple functions. The purpose of this particular taxonomy is simply to provide some conceptual and organizational framework for the ethical analysis of these new technologies and their applications.
4. Kennedy PR, Bakay RAE. Restoration of neural output from a paralyzed patient by direct brain connection. *NeuroReport* 1998;9(8):1707–11. For more background on the history of brain implants, see Maguire GQ, McGee EM. Implantable brain chips? Time for debate. *Hastings Center Report* 1999;29(1):7–13.
5. CNN.com. Brain implant devices approved for trials. Available at: http://www.webmd.com/stroke/news/20040415/Brain-Implants and http://www.cis.upenn.edu/~bracy/brain/.
6. For more information on Medtronic and the Medtronic network, see www.medtronic.com.
7. For more on the ethics of PDAs, see De Ville KA. The ethical implications of handheld medical computers in medicine. *Ethics & Health Care* 2003;6(1):1–4.
8. Bauer KA. Home-based telemedicine: A survey of ethical issues. *Cambridge Quarterly of Healthcare Ethics* 2001;10(2):137–46.
9. In the case of the elderly, externally worn transmitters and GPS are currently being used to monitor and track loved ones who suffer from Alzheimer's disease and other forms of dementia. For more on this, see http://www.politechbot.com/p-02876.html.
10. Ritchtel M. Voices in your head? Check that chip in your arm. *New York Times* 2002; November 10.
11. National Science Foundation and Food and Drug Administration. *Report of the Workshop on Home Care Technologies for the 21st Century.* Rockville, MD: NSF/FDA; 1999.
12. There is some concern that these new technologies would only be available to those persons who can afford them and, subsequently, lead to greater disparities in healthcare. This is a possibility. On the other hand, the use of such technologies could prove to be a less expensive way for healthcare centers and the state to provide healthcare services to more people. On the patient side, the use of these technologies could create less expensive and less burdensome ways for patients to obtain healthcare. This, of course, is not a question that can be answered a priori but rather an empirical issue that will need to be tested.
13. Although medicine in general has for many years placed an emphasis on prevention, the success of this emphasis is less than complete. Moreover, in the case of emergency medicine, its very nature as a reactive specialization makes prevention very difficult. Implants, however, may be able to change this, at least in a limited way.
14. Vicente K. *The Human Factor: Revolutionizing the Way People Live with Technology.* New York: Routledge Press; 2004.
15. Needless to say, all patients should be viewed as bio-psycho-social beings, as persons, not just bodies. Unfortunately, for a variety of reasons, not all healthcare professionals view their patients this way. Geographically distant and electronically mediated provider–patient interactions could exacerbate this undesirable behavior.
16. For information on the federal rules for governing investigational devices, see the Code of Federal Regulations, CFR 21, Part 812. This information can be obtained by searching the U.S. Food and Drug Administration's Web site.
17. Evans H. High-tech vs "high touch": The impact of medical technology on patient care. In: Clair M, Allman R, eds. *Sociomedical Perspectives on Patient Care*, Lexington, KY: The University Press of Kentucky; 1993.

18. Pellegrino E, Thomasma D. *The Virtues in Medical Practice.* New York: Oxford University Press; 1993.
19. Edelstein E. *The Hippocratic Oath.* Baltimore, MD: Johns Hopkins Press; 1943. Also see Miles S. *The Hippocratic Oath and the Ethics of Medicine.* New York: Oxford University Press; 2004.
20. Eng TR, Gustafson DH. *Wired for Health and Well-Being: The Emergence of Interactive Health Communication*. Washington, DC: Science Panel on Interactive Communication in Health, U.S. Department of Health and Human Services, 1999.
21. For more on legal and policy issues associated with this topic, see Lumpkin J. E-health, HIPPA, and beyond. *Health Affairs* 2000;19(6):149–51.