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Computers and Neurosurgery

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At the turn of the twentieth century, the only computational device used in neurosurgical procedures was the brain of the surgeon. Today, most neurosurgical procedures rely at least in part on the use of a computer to help perform surgeries accurately and safely. The techniques that revolutionized neurosurgery were mostly developed after the 1950s. Just before that era, the transistor was invented in the late 1940s, and the integrated circuit was invented in the late 1950s. During this time, the first automated, programmable computational machines were introduced. The rapid progress in the field of neurosurgery not only occurred hand in hand with the development of modern computers, but one also can state that modern neurosurgery would not exist without computers. The focus of this article is the impact modern computers have had on the practice of neurosurgery. Neuroimaging, neuronavigation, and neuromodulation are examples of tools in the armamentarium of the modern neurosurgeon that owe each step in their evolution to progress made in computer technology. Advances in computer technology central to innovations in these fields are highlighted, with particular attention to neuroimaging. Developments over the last 10 years in areas of sensors and robotics that promise to transform the practice of neurosurgery further are discussed. Potential impacts of advances in computers related to neurosurgery in developing countries and underserved regions are also discussed. As this article illustrates, the computer, with its underlying and related technologies, is central to advances in neurosurgery over the last half century.

In the Theater

D. Abse

Sister saying—'Soon you'll be back in the ward,'
sister thinking—'Only two more on the list,'
the patient saying—'Thank you, I feel fine';
small voices, small lies, nothing untoward,
though, soon, he would blink again and again
because of the fingers of Lambert Rogers,
rash as a blind man's, inside his soft brain.
If items of horror can make a man laugh
then laugh at this: one hour later, the growth
still undiscovered, ticking its own wild time;
more brain mashed because of the probe's braille path;
Lambert Rogers desperate, fingering still;
his dresser thinking, 'Christ! Two more on the list,
a cisternal puncture and a neural cyst.'
Then, suddenly, the cracked record in the brain,
a ventriloquist voice that cried, 'You sod,
leave my soul alone, leave my soul alone,'—

Key words
- Computers
- Neuroimaging
- Neurosurgery
- Technology

Abbreviations and Acronyms
CT: Computed tomography
MRI: Magnetic resonance imaging

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the patient's dummy lips moving to that refrain,
the patient's eyes too wide. And, shocked,
Lambert Rogers drawing out the probe
with nurses, students, sister, petrified.
'Leave my soul alone, leave my soul alone,'
that voice so arctic and that cry so odd
had nowhere else to go—till the antique
gramophone wound down and the words began
to blur and slow, '. . . leave . . . my . . . soul . . . alone . . .'
to cease at last when something other died.
And silence matched the silence under snow.

INTRODUCTION

The physician and poet Abse captured the difficulty of operating on the brain in the first half of the twentieth century in the haunting poem "In the Theater" (1). The poem was inspired by a story narrated by his brother:

> Only a local anaesthetic was given because of the blood-pressure problem. The patient, thus, was fully awake during the operation. But in those days, in 1938, in Cardiff, when I was Lambert Rogers' dresser, they could not locate a brain tumour with precision. Too much brain tissue was destroyed as the surgeon crudely searched for it; before he felt the resistance of it . . . all somewhat hit and miss. One operation I shall never forget . . . .

Technical developments in the field of neurosurgery since 1938 have made such an encounter a rare event. Most advances in medical sciences in the first half of the twentieth century were in the development of hemostasis, aseptic technique, and anatomic localization of disease. However, it was not until the development of imaging and microsurgical techniques in the second half of the century that surgeons were able to approach deep-seated brain lesions confidently. These developments marked the beginning of modern neurosurgery, rendering the disturbing scene described in Abse's poem part of history. Key to these technologic advancements is the invention and continued refinement of the modern computer.

At the turn of the twentieth century, the only computational device used in neurosurgical procedures was the brain of the surgeon. Today, most neurosurgical procedures rely at least in part on the use of a computer to help perform the surgery accurately and safely (15, 16). Only 20 years ago, having a cell phone was considered a luxury few could afford, high-speed Internet was reserved for college campuses, and a laptop was unheard of. Now college students own at least one wireless device, and most work with a cell phone, a laptop, and more commonly a tablet computer with more computing power than the computer aboard the original space shuttle. In one white-coat pocket, one can fit an entire neurosurgical library, and at the press of a few buttons one can access the Internet wirelessly to consult contemporary journals to help answer the questions that are subjects of current research. Neurosurgeons are as reliant on technology as the rest of the modern world (8).

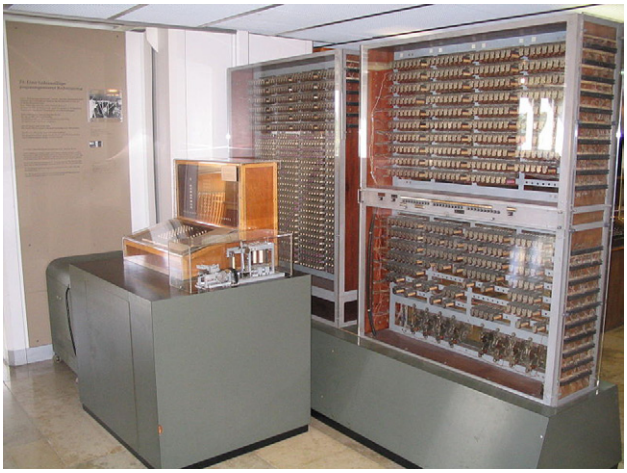

Figure 1. The Zuse Z3 is considered the world's first operational computer. Built by Konrad Zuse in 1941, it was programmable, was fully automated, and was later shown to be Turing complete. Program code and data were stored on punched film. (Original by Venusianer. Republished under the GNU Free Documentation License without alterations or additions.)

The techniques that revolutionized neurosurgery were mostly developed after the 1950s. Just before that era, the transistor was invented in the late 1940s, and the integrated circuit was invented in the late 1950s. During this time, the first automated, programmable computational machines were introduced (**Figure 1**). The rapid progress in the field of neurosurgery not only occurred hand in hand with the development of modern computers, but one also can state that modern neurosurgery would not exist without computers (**Figure 2**). The world in which the great neurosurgeons Dandy, Cushing, and Penfield operated was a largely analog world. Computers in the first half of the twentieth century relied on analog physical phenomena and were mostly immense mechanical devices reserved for large calculations. An example of these types of computers is the differential analyzer used to solve differential equations and systems of linear equations. The 1940s sparked the birth of the information age with the invention of the transistor (27). The world was later transformed forever in the next decade in what Asimov called "the most important moment since man emerged as a life form." The invention of the integrated chip by Noyce sparked a revolution in all aspects of human daily life. Noyce said that his invention was a challenge to the future and charged colleagues to "top that one" (2). In the decades that followed, this challenge was embraced in the form of moon landings, telescopes designed to scan and analyze galaxies light years away, unmanned aircraft, and technologies that allow us to explore the electrical activities that underlie consciousness. Although each of these accomplishments was a great technologic leap in human history, each relied significantly on the development of the integrated circuit and the massive surge in computing power it allowed. To place this in perspective, Hodgkin and Huxley solved their model of the propagation of the action potential in the late 1950s with the use of a mechanical calculator that required weeks to complete the com-