

GUEST EDITORIAL

Rehabilitation for the 21st Century

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"You'd better go check this out. That aircar was flying erratically and it's been off the screen for 5 minutes now," the shift commander said, looking my way.

"But chief, there's been no signal from any emergency personal distress unit," I said hopefully. It was late and my shift on the emergency medical response team had begun early that morning.

"I just have a feeling we should check this one out, and fast," she insisted. The chief often had such feelings and she was usually right. I was already moving toward my aircar as she finished speaking.

After flipping on the wide area emergency alert beacons, I headed the aircar out to the last recorded position of the now-missing vehicle. At a speed of just under Mach 1, it didn't take more than a few minutes. The crash wasn't hard to see, either. I flew right above it, then found a clear spot on which to land.

"Aircar down. Looks like a 2074 Yugo, license plate XTRAFAS." Yugo had been the first major 21st century automobile manufacturer to capitalize on the invention of the aircar, almost 25 years ago at mid-century. It was still the premium brand. I reached the cockpit compartment in less than one minute.

"Young male, unconscious; looks seriously injured," I relayed.

"Yes, looks like he's suffered multiple major trauma, including a head injury. I'll alert the surgical team." The chief was viewing the crash scene over the televideo link from my helmet-mounted transmitter.

He had a pulse and was breathing, so I strapped the life support and monitoring unit onto his arm and activated it. A closer visual inspection indicated a broken arm, a broken leg, probable blunt abdominal injury, and a nasty frontal head wound. I selected the neurotrauma sequence on the life support unit so it would inject him with the latest cocktail of neuroprotective agents.

"OK, let's foam him and transport," the chief transmitted. The life support foam made things

like that much easier. Invented in 2060, it had revolutionized emergency care—it supplied and maintained fluid and electrolytes, as well as continuous oxygen, through a fluid interface with the skin. It was also bactericidal, and provided immediate structural support to damaged bones. Once foam was applied, you could move patients without worrying about doing further damage.

By the time we reached the base the surgical team was scrubbed and ready. The chief had reached the victim's family and they were en route. I joined the chief in the conference room as our new patient was taken into the surgical suite.

"Robert Snead, age 22, university student. Lab results unremarkable except for the alcohol level of 0.12," the chief stated matter-of-factly.

I whistled. The legal limit for ground cars was 0.08. Alcohol, even in minute doses, impaired concentration, and flying an aircar with any detectable alcohol level was strictly prohibited. In fact, all aircars had alcohol detectors built into the ignition systems to prevent flying by pilots with detectable alcohol in their bodies. Of course, a bright kid with a few components and some determination could bypass the system.

"Parents will be here soon. You'll guide them through," she continued.

I nodded. It was the usual procedure. Families found it somehow soothing to be greeted and initiated into the complex world of trauma resuscitation and rehabilitation by the person who had first found their loved one. I looked at the wide-screen monitor that displayed the surgical suite. Robert was already prepped and draped. That was good. It made the scene look much more controlled for families.

Not much later, his parents arrived. They were pretty upset, but the orderly scene of the surgical suite had its paradoxically soothing effect. I reviewed with them how we had found him and what we knew so far. Robert's father grimaced as I mentioned the alcohol level. That was good,

too. We'd need their help in getting him to enter drug treatment, but that was in the future. Now it was time to explain the present.

"There are three surgical teams working. The general surgeons are repairing a ruptured spleen and a perforated colon. The orthopedic team is inserting the temporary, internal fixators to stabilize his broken bones, and the neurosurgical team is removing the areas of damaged brain and preparing the sites for the implants." Even with most of the surgery done by miniaturized robots, under the control of the surgeons, it was amazing that all of this could be accomplished simultaneously.

"What are the implants you're talking about?" his mother asked.

"Actually, there are several, different implants. The easiest to understand is the bone implant. While the surgeons were inserting the temporary fixators, they removed some of his normal bone cells. These cells will be cultured to obtain bone stem cells, and tomorrow the stem cells will be inserted back into the fracture sites. By the time the fixators have dissolved, the bone cells will have grafted and created new bone."

They nodded; this was pretty familiar to most people. Stem cell bone grafting had begun many years ago for treatment of particularly nasty fractures, ones in which huge areas of bone were simply crushed and missing. But surgeons discovered that bone healing with stem cell grafts for even ordinary fractures was so much more rapid, requiring only days instead of weeks, that it was now pretty much the standard of care for most fractures.

"The brain implant will also be grown from his brain-derived stem cells. It's a much more complex business and will take several days of preparation. In fact, I am going to introduce you to the rehabilitation team as soon as you're ready."

"He's still in surgery. Is it really appropriate to begin talking about rehabilitation now?" the boy's father asked.

A fair, but naïve question, I thought. People really still didn't understand the revolution that had taken place in rehabilitation.

"Absolutely. His rehabilitation starts right now. Let me introduce the team to you." I opened the door, and asked the rehab team to come in.

"Dr. Max Schnell is the rehabilitation physician leading the team."

Max walked over and shook hands with them. He was tall, lanky, and studious-looking. I knew the studious look was for real. Residencies in rehabilitation medicine were among the most sought after specialty training programs. The amount of knowledge needed to practice in this field had been growing exponentially and encompassed an incredibly wide range of specialties: neurobiology, tissue engineering, neurobehavior, robotics—the list went on and on. Fortunately, he had the other members of the team, whom he was now introducing to Robert's parents, to help him.

"Dr. Linda LaPlace is our neurobehavior specialist," Max stated.

I knew Linda well. We had dated for a time when she was studying for her PhD. She had explained to me how her field had matured since the late 20th and early 21st centuries. Long before I had entered training, the disciplines of speech pathology, occupational therapy, and neuropsychology had each begun separate training tracks in the fast-growing field of neurobehavior. Neurobehavior was a natural outgrowth of the progress in cognitive neuroscience, computer technology, and neurobiology. Before long, the emerging discipline had attracted most of the new trainees in these separate disciplines, and the graduates found that they had more in common than not. Without even meaning to, those portions of the old therapeutic disciplines merged into neurobehavior.

"Dr. Mark Speed is our sensorimotor modulation specialist," he continued.

At the same time that neurobehavior had been forming as a discipline, a similar transformation had occurred with therapies involving predominantly rehabilitation of movement and sensation. The advances in robotics, tissue engineering, and neurobiology had attracted a large number of physical and occupational therapists into the new discipline of sensorimotor modulation. It was hard to keep these specialists. Last year's sweeping U.S. Olympic victories and the endorsements by the Olympic teams hadn't helped. They had fueled an even greater demand from ordinary citizens who wanted their expertise to help them become better athletes.

"Our goal is to return your son to a productive life as soon as possible," explained Max. "This requires a lot of planning and we are going to need your help. The sooner we can start, the more likely it is that we will have a successful outcome."

"Will he be able to return to school?" asked Robert's father. "Probably, although there are no guarantees. It's really too early to tell," Max cautioned.

"When will he be able to return home?" queried Robert's mother. She was beginning to recover from the initial shock now.

"Not for at least a few weeks," answered Max. "We need to immerse him in the rehabilitation environment. But let me have Linda tell you about that and why your help is so important." He motioned to Linda, and she obliged. I enjoyed listening to Linda. She could explain the incredible complexities of neurobehavior clearly, without being condescending. Families instantly warmed up to her and trusted her. She was also stunning.

"Part of your son's brain was badly damaged—damaged beyond repair. Cells in that area of the brain were killed by the injury," she was saying. "But doesn't the neuroprotectant help?" asked Robert's mother, quizzically.

"Yes," Linda said, nodding agreement, "but the neuroprotectant can only help those cells not already killed by the impact. It helps cells that are damaged and at risk. Also, cells are at risk during the delay between the injury and when the neuroprotectant actually gets to them. That's why we encourage people to wear the emergency personal distress units. They contain neuroprotectants for injection in case of injury."

"I know," said Robert's father, his tone frustrated. "We just couldn't get Robert to agree to wear his. He said nothing would happen to him, and he didn't like being tracked."

"That's not unusual. They all think they're immortal," Linda said, smiling gently before continuing. "The damaged areas of brain served many important functions involved with thinking and language. The surgeons will have removed a number of neural stem cells at surgery. We can then grow a replacement section of brain for him." She paused; this is where it usually

became complicated. "However, this new section of brain now has to be integrated with his existing brain tissue."

"You mean you have to program in memories and skills from his past?" his father asked, puzzled.

"No, we can't actually do that. The replacement section will be unorganized when we insert it. We will have to work together with him to establish the replacement neural patterns in the new brain areas."

"He'll have to learn everything all over again?" his mother asked, looking daunted.

"No, just parts of his experiences. That's where you become so important. We need to configure a learning environment for him. As you know, we can simulate a vast range of experiences and use them to teach."

Both parents nodded. Virtual reality was now widely used in education as well as for leisure purposes.

"The special feature about our simulated environments is that we can monitor the functional organization of our patients' brains as we apply these stimuli. In that way we can more quickly tune the stimulation to teach the brain circuits the skills that are missing."

"What exactly do you need from us?" asked his father.

"Well, one of the difficult issues that we have just recently come to understand is how personality interfaces with learning. We used to think that personality was simply an emergent property of complex autonomous computing systems, but now we understand that there are "whole-field" characteristics to human brains. These whole-field characteristics are present very early in life, perhaps even at birth, and have subtle but pervasive influences throughout the brain. Now we understand that the learning environment has to be tailored as precisely as possible to the personality of the individual."

"And if it's not?" Both parents were looking intently at the neurobehaviorist as she began to answer.

"Then the learning just doesn't take as well. Progress is much slower, and the patient may never regain full function. That's why you're so important. We need to understand as much as

possible about Robert—who he is, what he likes, what he doesn't like, how he came to be the person he is."

"Can we make him a little more cautious?" his mother asked.

"Even if we could change his basic personality, I'm not sure we would be wise to do so. As it turns out, that's nearly impossible to do. So, if there are no more urgent questions, let's get started. Tell us about Robert..."

This futuristic medical encounter, while fanciful, is written deliberately to illustrate some of the opportunities and challenges faced by the field of rehabilitation. It is biased towards recently emergent trends in neuroscience and medicine, but if history is any guide, we have been overly conservative in our imaginings. In any event, we would like to discuss some of the issues it raises.

We have deliberately selected a traumatic event for illustration. Trauma has always been with us, and unless societies devote considerably more resources towards minimizing risk than they have traditionally been willing to do (1), trauma will continue to be a major cause of morbidity and mortality. Advances in communications and transport have contributed greatly to increased survival from trauma (2), and there is every reason to believe that our descendants will continue to capitalize on improvements in these technologies (3).

Medical care in the United States has been organized around the model of acute interventions (4) and we chose to illustrate a medical episode that began with a previously healthy individual facing a catastrophic event. However, by the mid-point of this century, our society will actually be composed of approximately 20 percent individuals over the age of 65 (5), who will consume the vast proportion of medical resources. Improvements in acute care have increased the number of survivors of catastrophic illness. There are currently approximately 5.3 million individuals in the U.S. living with significant disability due to traumatic brain injury (6), 250,000 due to spinal cord injury (7), and 3 million due to stroke (8). Nearly 15 percent of the population is limited in activity due to a chronic condition (9). Already, individuals with chronic disease account for about 70 percent of all health care expenditures in the U.S. (10). Thus, the financial pressures on the

medical care-delivery system make it highly likely that we will experience major changes in the delivery of health care services, especially rehabilitation. In the context of massive increases in the numbers of individuals eligible for and needing rehabilitation services, interventions with demonstrable benefit, as determined by well-designed, scientifically sound research, are likely to survive (11).

While acute care will inevitably retain the drama, we have tried to indicate that the resources of advanced technology will actually make acute care quite routine, while much of the real frontier will be in rehabilitation. To be sure, there are many advances to be made in resuscitation and trauma care, but the current evidence base for trauma care exceeds that for rehabilitation (12). Our understanding of the pathophysiology of acute neural injury is expanding rapidly, and trials of agents to decrease neuronal cell death after acute injuries are continuing, despite initial disappointments (13). Automatic defibrillators have already demonstrated their effectiveness for high-risk populations (14). Surgeons are already using robotic devices to aid in endoscopic surgery (15). Advances in replacing damaged tissues are already underway. Efforts to grow new heart valves in tissue culture are well along (16), while clinical trials of pig olfactory ensheathing cells to repair acute spinal trauma are being actively planned (17). The technical challenges to be surmounted in creating new, functionally connected replacement nervous tissue are vast.

What we seek to highlight here, though, are some of the human and organizational challenges facing rehabilitation. Just as the propensity for risk-taking behavior and substance abuse are likely to remain major causes of trauma and morbidity, so, too, will the need for personal relationships and valuation of each patient as an individual be requisite components of the rehabilitation process. However, the changing technology, the pressure of finances and demographics, and the conflicting demands of professional interests will inevitably lead to changes in the makeup and responsibilities of the rehabilitation team providing rehabilitation services.

The selections we made for our fictional example were arbitrary, but serve to illustrate

some points. The team process is currently enshrined in rehabilitation practice (18), but will become even more indispensable as the range of knowledge required to provide rehabilitation grows dramatically. It is extremely unlikely that any one discipline can routinely train its members to encompass all of the knowledge that will be necessary. However, it is likely that the practice boundaries of current rehabilitation professional groups will change. In the past fifty years, specialization has been a dominant force in medicine. Physical therapy, occupational therapy, speech therapy, respiratory therapy, and neuropsychology have emerged as separately recognized disciplines (19) as physician practice has become increasingly specialized (20).

How will the boundaries between disciplines be drawn in the future? We do not propose that the boundaries suggested in our fictional example are ideal, or even likely, but the literature of medical sociology suggests certain forces will constrain or expand possibilities. Over the last century, medicine has become both more specialized and more dependent on technology (21), and these trends can be expected to continue. In an article entitled "Countervailing Power: The Changing Character of the Medical Profession in the United States," Donald Light argues that the sovereignty of the medical profession appears to be growing with advances in specialized knowledge despite the development of now well-established, countervailing powers, such as managed care and utilization review, that limit the traditional autonomy of physicians. In this context, he suggests that "accountability," rather than a threat to the medical profession, "may be the profession's ace card" as governments and institutional buyers seek to manage medical practice and control health costs, thus highlighting the importance of solid data on which to base judgments of medical effectiveness and "professionalism." (22).

Both of these factors—solid data and professionalism—have special relevance to the future of medicine, as well as its past. The rise of scientific medicine and the role of science in demonstrating improvements in medical effectiveness have been identified as key factors in the professional dominance achieved by physicians following the founding of the American Medical Association in 1847

(21). More recently, the growing importance and influence of research on quality of care and health outcomes has been noted (23).

The increasing differentiation and greater complexity in medicine has been accompanied by growth in a highly complex web of occupational groups, with "turf wars" both among and within these groups (23). The problems that arise in introducing a new profession into medicine have been illustrated by the introduction of clinical pharmacists to the medical team. These include changes in the definition of work roles, threats to status of other professionals, blurring of boundaries, and tensions within the profession of medicine (24).

As new professions threaten the territorial domain and professional expertise of current professions on the rehabilitation team, similar difficulties may be anticipated, but turf wars are not a foregone conclusion. Over the past century, the notion of professionalism has been closely linked to embodying a core of technical expertise and a service orientation (23). These characteristics are recognized and respected among rehabilitation professionals, where a commitment to service is frequently reinforced through extended contact with our patients. Thus, where new practices are demonstrated to be more effective or more cost-effective, a solid commitment to service and value for our patients may ease the tensions of transition and changing professional boundaries.

In the future, the battleground for professional autonomy and sovereignty will grow more complex, as providers must negotiate with more payers, and it becomes more difficult for professional groups to defend their turf against evidence-based medicine. Five broad groups have been identified as constituting the external locus of countervailing pressures that exists along the boundaries of medicine, namely: a) *government*, including local, state, and federal; b) *corporate purchasers* of health care and their agents, including insurers and managed care providers; c) *corporate sellers*, such as manufacturers of pharmaceuticals and medical equipment; d) *consumers*, including various disability-advocacy groups; and e) *other providers* (23). There is no reason to believe that the influence of government, corporate purchasers, and corporate sellers will diminish in the future of rehabilitation. To the contrary, rehabilita-

tion must continue to compete for a share of medical spending in a context where other sectors of medicine are strong contenders. If the rehabilitation professions are diverted by turf wars in response to countervailing pressures and new developments in science, the field and our patients will suffer. Alternatively, if the field can build a sound foundation of scientific evidence for practice effectiveness (25), and cultivate the hallmarks of professionalism—prolonged training in a body of specialized, abstract knowledge, and an orientation toward providing a service (18)—rehabilitation can expect to play a vital and exciting role in the 21st century.

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