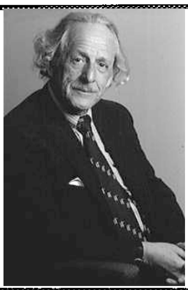
Essays of an Information Scientist: Science Literacy, Policy, Evaluation, and other Essays, Vol:11, p.325,1988
Current Contents, #41, p.3-12, October 10, 1988



Current Comments®

EUGENE GARFIELD
INSTITUTE FOR SCIENTIFIC INFORMATION®
3501 MARKET ST., PHILADELPHIA, PA 19104

Noninvasive Medicine. Part 1. No More Needles, Fear, or Pain

Number 41 October 10, 1988

This three-part essay explores the broad topic of painless, noninvasive medicine. The first part discusses the pain and anxiety often involved in medical treatment. It also documents the almost universal fear of needles. Alternatives, both for treating disease and controlling pain, include noninvasive drug delivery systems, neurostimulation, acupuncture, and hypnosis.

Many of the topics covered in these essays, as you might expect, reflect my own interests and experiences. My personal encounters with physicians in and out of hospitals may not be unique, but they have been sufficient to make me acutely aware of the anxiety and discomfort that many medical procedures entail. Consequently, after my last hospital experience, I resolved to explore noninvasive, or painless, medicine. I soon found out that this was indeed a formidable challenge.

The challenge lies mainly in defining the concept and scope of noninvasive medicine. My immediate interest is in the pain associated with medical treatment and ways to prevent it. A further interest—if the goal is painless medicine—is in assessing where medical practice stands. Therefore, this three-part essay will address, first, pain and the anxiety it generates; second, the goal of painless medicine and noninvasive diagnostic technologies; and, third, the further realization of that goal in painless and nontraumatic therapeutic techniques.

Painless Medicine

Most of us would agree that the ideal practice of medicine should ultimately be painless (yet effective) medicine. In practical terms, this means no invasion of the body (to diagnose or treat a disease, or to prepare to do either), where the actual invasion (or what results from it) causes pain. As will be noted in Part 3, the physician usually must enter (invade) the body in order to fix something that isn't working. The question is, Can modern medicine, with its progressively noninvasive techniques, do that without inflicting pain on the patient? I am not even thinking about surgery, where general or regional anesthesia is mercifully available. I am referring to all the procedures that take place before surgery (diagnostic tests, sedation, anesthesia) and after it (more evaluative tests and postoperative pain management). All these procedures, almost without exception, entail the use of needles.

In the pretreatment phase, many diagnostic procedures require the intravenous administration of contrast media. These chemicals enable radiologists to obtain better images. The most common diagnostic and/or preoperative procedure, however, continues to be the intravenous drawing of blood to assess various body functions. In the treatment phase, when surgery is involved, anesthesia—local, regional, or general—is administered, often through a vein. When treatment does not involve surgery, it usually means drug therapy. While drugs are given orally for most conditions, there are some diseases (such as cancer treated with chemotherapy) that also require drug administration through injection. After surgery, there are, generally, more tests (for example, blood tests) that are standard for evaluating the patient's progress. In addition, there is often pain resulting from the surgical procedure, which must be managed with painkillers, administered orally or parenterally (by some means other than the alimentary canal). Also after surgery, parenteral nutrition or medication is normal (glucose, antibiotics, and so on). It can quickly be seen, then, that needles are perhaps the most pervasive of all medical phenomena. Consequently, the following discussion focuses on needles, the fear they produce in children and adults, and alternatives to needles.

Needle Phobia

Since their invention in the 1830s,[1] needles and syringes have been a source of fear and discomfort. Karl E. Kassowitz, Milwaukee Children's Hospital, Wisconsin, has studied children's reactions to needles. During the first six months of life, there is no evidence of apprehension. This is undoubtedly due to a primitive cognitive system and the lack of previous experience. From that time until the end of the fourth year, most children exhibit strong, if not violent, reactions to "needling." From then on, in most children, there is gradual compliance and self-control—what is termed emotional maturity.[2] As many of us adults know (and may even admit), no matter how self-restrained we appear, the terror remains just below the surface. The unspeakable fear children have of needles is further substantiated by studies of children's poems and drawings.[3,4]

That this fear never really subsides in us may be seen in our avoidance, whenever possible, of hospitals, doctors, and, especially, dentists. Much has been written about needle phobia, particularly in dental patients. For example, a report by Stanley F. Malamed, University of Southern California, Los Angeles, and Christine L. Quinn, University of California School of Dentistry, Los Angeles, on the electronic stimulation of nerves to block pain, concludes that the best candidates for this technique are those who are afraid of needles or appear to be allergic to local anesthetics. They further suggest that "the overwhelming majority of these [allergic] responses are psychogenic (fear related) in nature."[5] Another report, by Donald R. Morse, Temple University School of Dentistry, Philadelphia, and Bernard B. Cohen, Department of Psychology, West Chester State College, Pennsylvania, describes the use of psychological desensitization in dental patients with needle phobia.[6] Dennis C. Turk, Center for Pain Evaluation and Treatment, University of Pittsburgh School of Medicine, Pennsylvania, reminds us, however, that, while most people are fearful of needles, "the incidence and prevalence of full-blown needle phobia is less frequent than implied" in the research literature.[7] Still, the documentation of needle phobia that exists can only underscore the need for alternative methods.

Alternatives to Needles for Drug Delivery

There are two contexts in which alternatives to needles may reasonably be sought. One could be called input/output—that is, putting something into the body (medication) or taking something out (blood samples, biopsy specimens, and so on). The other context is the more avoidable one of needles used to administer anesthetic or analgesic agents. Alternatives to needles in both contexts are discussed in this essay.

The earliest instrument to challenge the supremacy of the needle and syringe was the jet injector. The benefits and drawbacks of this needleless system, introduced in the 1940s, were initially discussed in 1947 by Robert A. Hingson and James G. Hughes, Departments of Anesthesiology and Pediatrics, University of Tennessee, Memphis.[8] Among the advantages mentioned are the absence of pain, the ease of administration, and better sterility control. Some of the disadvantages still apply today—tissue injury and too wide a dispersion of injected material. This last objection was the topic of a more recent report (discussed in a letter to *Lancet*[9]) by P.M. Gaylarde and I. Sarkany, Royal Free Hospital, London, UK. Their research demonstrates that jet injectors, particularly for insulin users, deliver doses that may be too small and too variable.[10] Although this method of injection is not indicated for diabetics, it does seem to be the preferred method for routine or mass vaccinations.[11,12]

More recently, the search for needle alternatives has produced a variety of "drug delivery systems." These are reviewed by Ping I. Lee and William R. Good, Ciba-Geigy Corporation, Ardsley, New York,[13] and include drug pump systems and transdermal drug patches.

Drug pump delivery systems have successfully been used for diverse medical conditions. They come in a variety of shapes and sizes and are worn on the body or implanted subcutaneously. Some of these devices consist of self-regulating pumps, with drug reservoirs that are filled at specified intervals. The pump chambers lead to a catheter that is positioned into a vein. One variation is the subcutaneous injection port, which allows easy and painless access to a vein for delivering drugs, blood products, and nutritional fluids. These intravenous drug delivery systems are used most often to deliver insulin to diabetics[14] and chemotherapy to cancer patients.[15] Not only are injection ports good for delivering drugs, but they can also be used to obtain blood samples, thereby avoiding painful and repetitive venipuncture.[16]

Transdermal Delivery Systems

Perhaps the most impressive advances in the search for needle alternatives, however, have been in transdermal delivery systems. To some extent, this technology depended initially on a better understanding of skin characteristics. Among recent studies of the skin is a publication by Albert M. Kligman, Department of Dermatology, University of Pennsylvania School of Medicine, Philadelphia. He notes that skin, long believed to be an impermeable barrier, is now (and has been, for the past decade or so) recognized as a useful reservoir for the slow, steady release of drugs.[17] Also, according to Richard H. Guy and colleagues, Departments of Pharmacy and Pharmaceutical Chemistry, University of California, San Francisco, there are many advantages and some limitations to transdermal drug delivery.[18] Among the advantages is the avoidance of gastrointestinal and hepatic first pass metabolism, where some of the active drug ingredient is deactivated. Drugs delivered in this way also tend to minimize variability in drug administration and concentrations. Furthermore, the duration of the drug's effect is extended—which generally means a lower dose than that required for oral administration. Finally, unlike oral or intravenous medication, the drug can be withdrawn instantaneously if adverse effects set in. The major limitation mentioned in Guy's study is that transdermal drugs must meet certain criteria.[18] For instance, the drug's molecular size must be such that it can penetrate the skin. The drug must also be simultaneously oil- and water-soluble in order to pass through the different layers of the skin. These criteria have so far disqualified certain drugs from this delivery method—insulin, for example (because of its large molecules).

Many of the transdermal patch's limitations, however, are being addressed by pharmaceutical research, and one hopes it is only a matter of time before this technology will begin to serve a wider range of patient needs. Even the transdermal delivery of insulin, a large peptide molecule, will soon be possible. Yie W. Chien *et al.*, Controlled Drug Delivery Research Center, Rutgers—The State University of New Jersey, New Brunswick, have developed a special instrument called the "transdermal periodic iontotherapeutical system."[19] This device, now under evaluation, uses a physiologically acceptable level of electrical current that allows insulin to penetrate the skin. Not only will the new system effectively deliver insulin through the skin, but it will also meet the diabetic's unique physiological needs, allowing insulin to be administered right after meals, when it is most needed. Chien, with Chia-Shun Lee, College of Pharmacy, Rutgers, has also been developing a new generation of transdermal drug delivery systems that contain skin permeation enhancers, which modify the skin's barrier properties.[20]

Transdermal drug delivery has been extremely successful in the treatment of some conditions. The first and most common ailment to be treated transdermally was motion sickness. Developed by the ALZA Corporation, Palo Alto, California, a dime-sized disk, worn behind the ear, releases the drug scopolamine through the skin, preventing motion sickness for up to three days. ALZA, incidentally, has also been developing other means of painless drug delivery, namely, oral osmotics and inhalants. Its OROS System works by placing the active ingredient inside a semipermeable capsule that has a laser-drilled hole. As the semipermeable shell of the capsule absorbs fluid from the gastrointestinal tract, the osmotically active salt begins to dissolve, and the osmotic (water) pressure forces the active ingredient out of the tiny hole at a controlled rate. An inhalant, or nasal spray, for insulin users is also under development, but it is not expected to be on the market until 1992.

Transdermals are also used to control hypertension. Michael A. Weber, Hypertension Center, Veterans Administration Medical Center, Long Beach, California, finds that "transdermal administration of clonidine appears to be safe and effective, and may be an attractive alternative in patients complaining of symptomatic side effects or in those who have difficulty adhering to their prescribed oral regimens."[21] Elsewhere, he and Jan I.M. Drayer, University of California, Irvine, also remark on the control of blood pressure achieved with relatively low plasma concentrations of the drug and on patients' enthusiasm for this form of therapy, which neither hampers their everyday activities nor relies on their remembering to take their medication.[22]

Another group of heart patients is being helped by transdermal patches. A review article by Jan R. Weber, Department of Clinical Medicine, University of Pennsylvania Hospital, Philadelphia, concludes that, with transdermal nitroglycerin, "80% to 90% of patients with coronary artery disease may be expected to experience a reduction in angina frequency, an improvement in exercise performance, and enhancement in the quality of life."[23]

An alternative to transdermal delivery is transmucosal delivery (via the buccal cavity). Some research suggests that this is a superior delivery route—for example, papers by N.S. Khurmi *et al.*, Department of Cardiology, Northwick Park Hospital, Harrow, UK,[24] and by V.I. Metelitsa *et al.*, USSR Cardiology Research Center, Academy of Medical Sciences, Moscow.[25] So, for patients with chronic stable angina pectoris, the transmucosal route appears to be slightly more effective than the transdermal route. The blood level of the drug declines faster than it does transdermally. Transmucosal nitroglycerin, for example, was found to be absorbed much more quickly and to increase exercise tolerance significantly.

Aside from their use in the treatment of motion sickness, hypertension, and heart disease, transdermal patches are used to deliver estrogen, narcotic analgesics, antihistamines, birth control drugs, and even nicotine (as a less harmful way to wean smokers from cigarettes). As the above sampling of drug release systems indicates, transdermal and transmucosal patches provide the most promising delivery routes, both in terms of their noninvasive nature and their efficacy in delivering just the right amount of medication.

Alternatives to Needles for Pain Relief

The second context in which alternatives to needles must be found is for the prevention or management of pain. Pain is a complex and elusive subject that has long defied understanding or definition—in neurophysiology, psychology, and medicine. There is general agreement, however, that pain has both a physiological and a psychological component. These are by no means independent of each other. It is precisely this fact that makes the treatment of pain so difficult.

The short discussion that follows will be concerned only with acute (not chronic) pain. Along with the ether mask, needles have again traditionally been the instruments used to administer anesthetic or analgesic drugs before and after surgery. Alternatives that would eliminate both the pain and the anxiety associated with needles are of wide interest. The remainder of this essay, then, will touch upon techniques such as neurostimulation, acupuncture, hypnosis, and other behavioral strategies for preventing or relieving acute pain. Some research-front data on pain perception and management will also be presented.

As was said earlier, pain is not just a physical and biochemical response to a noxious stimulus; it is also an affective response to that stimulus. Also suggested earlier (in research on children's fear of needles) is the notion that this affective response, through repeated experiences of pain, manifests itself in anticipatory anxiety.

Transcutaneous Electrical Nerve Stimulation

Electrostimulation is proving to be an effective technique for pain relief. One particular technology, getting a lot of attention recently, is transcutaneous electrical nerve stimulation (TENS). Since Greco-Roman times, electricity has been used as a means of pain relief.[26] Stimulators have been developed for use on peripheral nerve endings as well as on the central nervous system, with a fair amount of success. A recent review article, by Jay Jong Choi and Chi L. Tsay, Department of Anesthesiology, Pain Management Center, New Jersey Medical School, University of Medicine and Dentistry of New Jersey, Newark, notes that TENS has gained "increasing acceptance as a noninvasive method for management of pain."[26] An earlier study for the Office of Health Technology Assessment, by Dennis J. Cotter, National Center for Health Services Research, Rockville, Maryland, concludes that "TENS for the treatment of acute postsurgical incision pain has become an accepted alternative to conventional methods of treatment."[27]

Acupuncture

Another ancient, yet also modern, technique for the relief of pain (and disease) is acupuncture. Acupuncture might at first glance seem to violate our "no needles" rule. However, the "insertion of needles is performed as quickly and painlessly as possible. A needle guide can be used to facilitate rapid insertion through the skin. When the needles are placed successfully, the patient is likely to experience a sensation known as 'Teh Chi,' which is described as a feeling of fullness, numbness, tingling, warmth, and/or soreness."[28] A variation of this technique is described by Ronald S. Shapiro, Department of Medicine, Medical College of Ohio, Toledo, where acupuncture magnets were applied to diseased or painful areas with immediate relief.[29] Finally, a logical extension of acupuncture worth noting is laser acupuncture, or laser photobiostimulation. This does away with the minor but still "unpleasant needling of acupuncture."[30]

Hypnosis

Hypnosis seems to work in preventing or controlling pain partly by reducing anxiety. Indeed, as psychiatrists Herbert Spiegel and David Spiegel, Stanford University School of Medicine, California, suggest, "hypnosis is simply a shift in concentration."[31] As far back as 1961, psychologist Ronald Melzack, McGill University, Montreal, Quebec, Canada, discussed this view. He points out that prizefighters and other athletes can sustain severe injuries without being aware that they have been hurt. "Almost any situation that attracts intense, prolonged attention may diminish or abolish pain perception."[32] The role of hypnosis in the relief of pain was the subject of a previous essay,[33] and so it will not be dwelt on here. However, the power of hypnosis and suggestion in controlling pain should not be underestimated. More than one clinical study has demonstrated its value in pre- and postoperative settings. Papers by clinical psychologist Barry R. Snow, Hospital for Joint Diseases Orthopaedic Institute, New York,[34] and L. Chertok and colleagues, Dejerine Psychosomatic Medicine Center, Paris,[35] illustrate this line of research.

According to Turk, however, "research on the efficacy of acupuncture and hypnosis in pain control continues to be controversial."[7] He suggests that strategies that are directly under the pain sufferer's control can be more effective. Some of these are discussed below.

Besides hypnotic suggestion, there are other behavioral techniques that can help control acute pain and anxiety. Morse and Cohen, mentioned earlier, state, "A technique used successfully in psychology to overcome phobias is systematic desensitization. The underlying concept...is that fear and relaxation cannot occur simultaneously."[6] Another approach to reduce stress and pain involves cognitive-behavioral therapy. This is illustrated in research done by Susan M. Jay *et al.*, University of Southern California School of Medicine.[36] Their work attempts to modify thought and behavior patterns through the use of a variety of techniques. One of these, for example, is "filmed modeling." Children are videotaped narrating the steps of the medical procedure and describing their thoughts, feelings, and positive coping behaviors. Other techniques are breathing exercises, imagery/distraction strategies, and behavior rehearsal. Such behavioral and cognitive strategies are aimed at reducing children's distress before painful medical procedures. And, indeed, this type of therapy resulted in lower levels of distress, lower pain ratings, and lower pulse rates.

This approach—psychological preparation before surgery or other painful procedures—has proven effective with adults as well. A frequently cited paper by anesthesiologist Lawrence D. Egbert *et al.*, Massachusetts General Hospital, Boston, strongly suggests that preoperative explanations and instructions to the patient as well as postoperative encouragement help in reducing pain and recovery time.[37] Another study, by Frances Cohen and Richard S. Lazarus, Department of Psychology, University of California, Berkeley, investigates the relationship between modes of coping with preoperative stress and recovery from surgery.[38] After classifying a group of surgical patients into those with avoidance versus vigilance coping strategies, the authors found that avoiders had less complicated recoveries. This finding may suggest that vigilants, who tend to consider all possible surgical complications, may experience higher levels of anxiety and helplessness. On the other hand, Egbert's research demonstrates that informed patients fare better postoperatively.[37] It is quite likely that the variables (of personality, situation, and so on) studied in each research project were different.

The degree to which a patient is made to feel helpless or out of control has a great deal to do with the overall outcome of medical treatment. This can be seen in recent investigations in another area of pain management. For postsurgical pain, an approach that is gaining adherents is patient-controlled analgesia (PCA), or the intravenous self-application of narcotics. As R.E.S. Bullingham, Pain Relief Research Unit, Abingdon Hospital, Oxford, UK, argues, since "inter- and intraindividual variability are the key factors in the optimum management of postoperative pain...success largely depends on transferring control to the patient."[39] PCA has many advantages, according to Bradley M. Rodgers *et al.*, University of Virginia School of Medicine, Charlottesville—whether used in adult or pediatric surgery.[40] Patients feel positive about having control over their own analgesia, and nursing-staff time is spared for other duties. Also, the dosage, which is preprogrammed to prevent overdosing, has a faster action when self-administered intravenously and on demand than when given intramuscularly and at fixed times. More than one study has found that adequate pain relief is often achieved with less analgesia.[40,41] It is through such techniques as psychological preparation and PCA that patients can now look forward to medical treatment with considerably less pain.

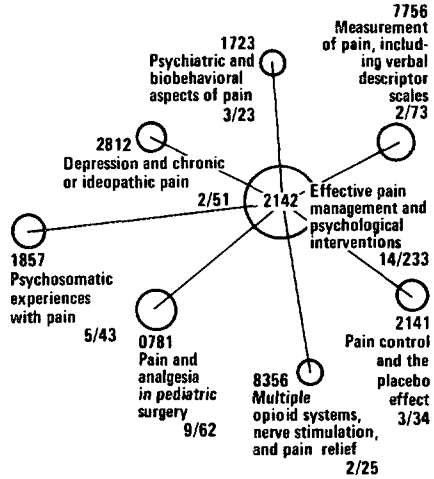
Research-Front Data on Pain

Figure 1 shows the citation links between C1-level research fronts that deal with pain—its perception, measurement, and management. The largest and most central of the research areas is "Effective pain management and psychological interventions" (#87-2142). Melzack, mentioned earlier, published 3 of the 14 core papers. The most-cited core paper (1,250 citations as of 1987) was coauthored by Melzack and Patrick D. Wall, then of the Department of Biology, Massachusetts Institute of Technology, Cambridge. It proposed the now familiar "gate control" theory of pain.[42] As described by the authors in a *Citation Classic®* commentary,

> [This] theory proposes that the dorsal horn of the spinal cord acts like a gate which modulates the flow of nerve impulses from the peripheral fibers to the central nervous system. The gate is influenced by peripheral fiber activity and by descending influences from the brain.... Pain is determined by many factors in addition to injury—by past experiences, culture, attention, and other activities in the nervous system at the time of injury.... The *concept* that injury-signals can be radically modified and even blocked at the earliest stages of transmission in the nervous system is now virtually universally accepted.[43]

As seen from the core papers on pain and from the pain management techniques discussed here, Melzack and Wall's theory has provided a framework for many of the subsequent, multidisciplinary approaches to pain assessment and control. One of the most fascinating areas in pain research involves the study of the placebo effect. This subject is discussed in several recent papers and in three core papers for research front #87-2141, "Pain control and the placebo effect," also shown on the C2 map (Figure 1). One of the current citing papers, by John M.H. Rees, University of Manchester School of Medicine, UK, is a 1987 review of research on endogenous opioids. The author lists various methods of pain relief that do not use drugs. Placebos are included, along with direct electrical stimulation, acupuncture, exercise, and stress. From the studies reviewed, Rees concludes that "placebo analgesia is a real biological

Figure 1: The 1987 C2-level map for research front #87-0340, "Pain perception and management," showing links between C1-level research fronts. The numbers of core/citing items are given after the research-front name.



event...[with] patients claiming satisfactory pain relief to be between 20 and 50%."[44] The 1955 core paper by Henry K. Beecher, Anesthesia Laboratory, Harvard Medical School, Boston, and Massachusetts General Hospital, deals entirely with this topic. Beecher's highly cited work suggests that placebos (or the placebo effect, whether in dummy pills or in active drugs) figure very strongly in "the reaction or processing component of suffering, as opposed to...the original [physical] sensation." It also demonstrates that "placebos are most effective when the stress (anxiety or pain, for example) is greatest."[45] Noninvasive indeed is the relief of pain (and anxiety) by suggestion alone.

Table 1 lists a few more research fronts on various aspects of pain and its management. One of the largest is #87-1727, "Recent developments in medical hypnosis," with 113 citing and 15 cited papers. A useful current paper by Fred H. Frankel, Beth Israel Hospital, Boston, reviews nonpsychiatric medical uses of hypnosis—for example, to reduce pain and the anxiety associated with it for surgical patients, among others.[46] Core to the same research front is

Table 1: Pain management. A = number of core papers and B = number of published papers in 1987 *SCI®/SSCI®* research fronts.

Number	Name	A	B
87-1727	Recent developments in medical hypnosis	15	113
87-1910	Endogenous pain control mechanisms	2	61
87-2088	Current concepts on analgesics and pain	8	50
87-2163	Pharmacokinetics of epidural and intraspinal anesthesia	32	262
87-2301	Preoperative pain management	5	47
87-3699	Pain perception and personality measures	6	42
87-7468	Opioid and nonopioid forms of analgesia	4	100
87-8191	Uses of acupuncture for pain relief	2	10
87-8527	Cultural perceptions of pain and health	2	24

a highly cited study of the role of hypnosis in alleviating pain, by psychologists Ernest R. Hilgard and Josephine R. Hilgard, Stanford University.[47] Their work, discussed in an earlier essay,[33] deals with hypnosis and analgesia. Worth reiterating is the distinction they make between pain as such, caused by a noxious stimulus, and the suffering that pain generates in some people. It is oftentimes in the latter region, of psychological affect, that hypnosis becomes an effective approach.

Two much smaller fronts deal with other work in the study and management of pain. Research front #87-8191, "Uses of acupuncture for pain relief," has two core papers, both published in 1986. One, by psychologist C.A. Vincent, University College, London, and P.H. Richardson, United Medical and Dental Schools, St. Thomas' Hospital, London, is an evaluation of acupuncture as a therapeutic technique.[48] The other, by the same authors, is a review of acupuncture in the relief of pain. From their evaluation of the research in this field, they point out the success of this technique in the short-term relief of pain and the significance of point location.[49]

Finally, "Cultural perceptions of pain and health" (#87-8527) deals with the less clinical and more psychosocial study of pain perception and assessment. One of the two core papers for this small but important research area is by Irving K. Zola, Department of Sociology, Brandeis University, Waltham, Massachusetts. He postulates a socially conditioned selective process that accounts for epidemiological differences between societies or communities. To test this hypothesis, Zola studied groups of Italian and Irish patients. He found that the two cultural groups differed widely in how they described their symptoms. He further suggests that the illness behavior of the two groups manifests "prescribed defense mechanisms of their respective cultures—with the Irish handling their troubles by denial and the Italians, theirs by dramatization."[50] What is said here about differences in ethnocultural groups may also pertain to individuals. Indeed, as Bernard Tursky, State University of New York, Stony Brook, argues, an individual's unique way of reacting to pain should become a routine part of a medical record, along with blood pressure and other vital signs. He proposes the development of a pain perception profile—to aid the physician or nurse in choosing the most appropriate pain control method.[51] So, for some patients, morphine might be indicated—while for others, reassurance concerning their prognosis may be adequate.

Conclusion

As unpleasant or even traumatic as pain can be, it is necessary for survival. Numerous instances are reported in the literature of children born with some neural abnormality that prevents them from sensing pain.[52,53] These children suffer serious burns, bruises, and other mutilations but can do nothing to protect themselves. And where would doctors be without their patients showing them "where it hurts"?

There is no denying, then, that pain is essential for health and survival—in its role as alarm system to patient and caregivers alike. However, we can still hope for effective methods to selectively remove pain once it has sounded an alert. While pain is often essential for proper diagnosis, it need no longer be tolerated in the treatment phase (during or after a therapeutic intervention). Its negative effects on the psyche at this point far exceed its physical benefits.

Clearly the trend in modern medicine is toward less and less invasive (and hence less painful) medicine. The day is not far off when Isaac Asimov's vision in *Fantastic Voyage* may metaphorically come true. In this fascinating book, subsequently made into a film, a submarine, smaller than a blood cell and manned with doctors and technicians, is injected into the blood vessels of an ailing man to perform some repair work.

Many physics and engineering laboratories are currently involved in designing and even building microscopic motors, movers, and sensors—with medical applications already in view. Currently being tested, for example, are "electronic pills" that upon ingestion send back radio messages about body function and chemistry. R.H. Colson *et al.*, Departments of Medical Electronics, Gastroenterology, and Child Health, St. Bartholomew's Hospital, London, have designed a new radiotelemetry capsule. Among its clinical applications is the measurement of gastrointestinal pH in humans and of extracellular pH in laboratory animals.[54]

Such extensions of microtechnology have a strong proponent in K. Eric Drexler, Stanford University, who uses the term "nanotechnology" to refer to this new engineering trend. He describes it as "the miniaturisation of bulk processes" (while microtechnology is based on their molecular manipulation). In other words "microtechnology promises to fit a transistor into a cube 0.1 micrometre on a side; nanotechnology promises to fit an entire computer CPU into the same volume."[55] This area of research shows great promise in the quest for medical treatment that is effective, affordable, noninvasive, and, best of all, free of pain.

* * * * *

My thanks to C.J. Fiscus and Sanaa Sharnoubi for their help in the preparation of this essay.

REFERENCES

1. **Schwidetzky O.** History of needles and syringes. *Anesth. Analg.* 21:34-8, 1944.
2. **Kassowitz K E.** Psychodynamic reactions of children to the use of hypodermic needles. *J. Dis. Child.* 95:253-7, 1958.
3. **Lewis N.** The needle is like an animal: how children view injections. *Child. Today* 7(1):18-21, 1978.
4. **Fassler D & Wallace N.** Children's fear of needles. *Clin. Pediat.* 21:59-60, 1982.
5. **Malamed S F & Quinn C L.** Electronic dental anesthesia in a patient with suspected allergy to local anesthetics: report of case. *J. Amer. Dent. Assn.* 116(1):53-5, 1988.
6. **Morse D R & Cohen B B.** Desensitization using meditation-hypnosis to control "needle" phobia in two dental patients. *Anesth. Prog.* 30(3):83-5, 1983.
7. **Turk D C.** Personal communication. 6 September 1988.
8. **Hingson R A & Hughes J G.** Clinical studies with jet injection. A new method of drug administration. *Curr. Res. Anesth. Analg.* 26:221-30, 1947.
9. **Gaylarde P M & Sarkany I.** Letter to editor. (Jet injection of insulin.) *Lancet* 1:1513, 1985.
10. **Gaylarde P M, MacMillan A L & Sarkany I.** Penetration and dose of injections with the Porton jet injector. *Brit. J. Dermatol.* 86:83-6, 1972.
11. **Parker V.** Jet gun or syringe? A trial of alternative methods of BCG vaccination. *Public Health Lond.* 98:315-20, 1948.
12. **Hingson R A, Davis H S & Rosen M.** Clinical experience with one and a half million jet injections in parenteral therapy and in preventive medicine. *Milit. Med.* 128:525-8, 1963.
13. **Lee P I & Good W R.** Overview of controlled-release drug delivery. *ACS Symp. Ser.* 348:1-13, 1987.
14. **Rønn B, Mathiesen E R, Vang L, Lørup B & Deckert T.** Evaluation of insulin pump treatment under routine conditions. *Diabetes Res. Clin. Pract.* 3:191-6, 1987.
15. **van der Staak F, Bökkerink J, Lippens R & Severijnen R.** Totally implantable systems for intravenous drug delivery. Experiences in children with cancer. *Z. Kinderchir.* 41:39-42, 1986.
16. **Isaacson G, Mansfield P F & Kirland M L.** An atraumatic technique for diagnostic phlebotomy. *N. Engl. J. Med.* 313:1478, 1985.
17. **Kligman A M.** Skin permeability: dermatologic aspects of transdermal drug delivery. *Amer. Heart J.* 108:200-6, 1984.

18. **Guy R H, Hadgraft J & Bucks D A W.** Transdermal drug delivery and cutaneous metabolism. *Xenobiotica* 17:325-43, 1987.
19. **Chien Y W, Siddiqui O, Sun Y, Shi W M & Liu J C.** Transdermal iontophoretic delivery of therapeutic peptides/proteins. I: insulin. *Ann. NY Acad. Sci.* 507:32-51, 1987.
20. **Chien Y W & Lee C-S.** Transdermal drug delivery system with enhanced skin permeability. *ACS Symp. Ser.* 348:281-300, 1987.
21. **Weber M A.** Transdermal antihypertensive therapy: clinical and metabolic considerations. *Amer. Heart J.* 112:906-12, 1986.
22. **Weber M A & Drayer J I M.** Clinical experience with rate-controlled delivery of antihypertensive therapy by a transdermal system. *Amer. Heart J.* 108:231-6, 1984.
23. **Weber J R.** Recent studies on transdermal nitroglycerin patch efficacy. *Amer. Heart J.* 112:238-41, 1986.
24. **Khurmi N S, O'Hara M J, Bowles M J, Whittington J R, Lahiri A & Raftery E B.** Transmucosal and transdermal nitroglycerin delivery systems for prevention of chronic stable angina pectoris. *Brit. J. Clin. Pract.* 40:187-91, 1986.
25. **Metelitsa V I, Martsevich S Y, Piotrovskii V K, Ryabokon O S & Blagodatskikh S V.** New transdermal and transmucosal nitroglycerin delivery systems in patients with ischaemic heart disease. *Eur. J. Clin. Pharmacol.* 32:5-10, 1987.
26. **Choi J J & Tsay C L.** Technology of transcutaneous electrical nerve stimulation. (Wu W-H & Smith L G, eds.) *Pain management: assessment and treatment of chronic and acute syndromes.* New York: Human Sciences Press, 1987. p. 137-65.
27. **Cotter D J.** Overview of transcutaneous electrical nerve stimulation for treatment of acute postoperative pain. *Med. Instrum.* 17:289-92, 1983.
28. **Lin R L.** Acupuncture. (Wu W-H & Smith L G, eds.) *Pain management: assessment and treatment of chronic and acute syndromes.* New York: Human Sciences Press, 1987. p. 166-75.
29. **Shapiro R S.** Rapid, effective non-invasive treatment of pain and disease with acupuncture magnets. *Amer. J. Acupuncture* 15:43-7, 1987.
30. **Choi J J, Srikantha K & Wu W-H.** A comparison of electro-acupuncture, transcutaneous electrical nerve stimulation and laser photo-biostimulation on pain relief and glucocorticoid excretion. *Acupuncture Electro-Ther. Res.* 11:45-51, 1986.
31. **Spiegel H & Spiegel D.** *Trance and treatment: clinical uses of hypnosis.* Washington, DC: American Psychiatric Press, 1987. p. 254.
32. **Melzack R.** The perception of pain. *Sci. Amer.* 204(2):41-9, February 1961.
33. **Garfield E.** Taking the hype out of hypnosis and a look at its entrancing use in pain control. *Current Contents* (3):3-9, 19 January 1987.
34. **Snow B R.** The use of hypnosis in the management of preoperative anxiety and postoperative pain in a patient undergoing laminectomy. *Bull. Hosp. Joint Dis. Orthopaed.* 45:143-9, 1985.
35. **Chertok L, Michaux D & Droin M C.** Dynamics of hypnotic analgesia: some new data. *J. Nerv. Ment. Dis.* 164:88-96, 1977.
36. **Jay S M, Elliott C H, Katz E & Siegel S E.** Cognitive-behavioral and pharmacologic interventions for children's distress during painful medical procedures. *J. Consult. Clin. Psychol.* 55:860-5, 1987.
37. **Egbert L D, Battit E W, Welch C E & Bartlett M K.** Reduction of postoperative pain by encouragement and instruction to patients. *N. Engl. J. Med.* 270:825-7, 1964.
38. **Cohen F & Lazarus R S.** Active coping processes, coping dispositions, and recovery from surgery. *Psychosom. Med.* 35:375-89, 1973.
39. **Bullingham R E S.** Optimum management of postoperative pain. *Drugs* 29:376-86, 1985.
40. **Rodgers B M, Webb C J, Stergios D & Newman B M.** Patient-controlled analgesia in pediatric surgery. *J. Pediat. Surg.* 23(3):259-62, March 1988.
41. **Lehmann K A & Tenbuhs B.** Patient-controlled analgesia with nalbuphine, a new narcotic agonist-antagonist, for the treatment of postoperative pain. *Eur. J. Clin. Pharmacol.* 31:267-76, 1986.
42. **Melzack R & Wall P D.** Pain mechanisms: a new theory. *Science* 150:971-9, 1965.
43. ————. Citation Classic. Commentary on *Science* 150:971-9, 1965. (Barrett J T, ed.) *Contemporary classics in the life sciences. Vol. 1: cell biology.* Philadelphia: ISI Press, 1986. p. 309.
44. **Rees J M H.** Endogenous opioids. *Bailliere. Clin. Rheumatol.* 1:27-56, 1987.
45. **Beecher H K.** The powerful placebo. *J. Amer. Med. Assn.* 159:1602-6, 1955.
46. **Frankel F H.** Significant developments in medical hypnosis during the past 25 years. *Int. J. Clin. Exp. Hypn.* 35:231-47, 1987.
47. **Hilgard E R & Hilgard J R.** *Hypnosis in the relief of pain.* Los Altos, CA: Kaufmann, 1983. 294 p.
48. **Vincent C A & Richardson P H.** The evaluation of therapeutic acupuncture: concepts and methods. *Pain* 24:1-13, 1986.
49. **Richardson P H & Vincent C A.** Acupuncture for the treatment of pain: a review of evaluative research. *Pain* 24:15-40, 1986.
50. **Zola I K.** Culture and symptoms—an analysis of patients' presenting complaints. *Amer. Sociol. Rev.* 31:615-30, 1966.
51. **Tursky B.** The development of a pain profile: a psychological approach. (Weisenberg M & Tursky B, eds.) *Pain: new perspectives in therapy and research.* New York: Plenum Press, 1976. p. 171-94.
52. **Hrbek V.** Agnosia of pain. Schilder and Stengel syndrome of so called asymbolia of pain. *Acta Univ. Palacki. Olomuc. Fac. Med.* 77:123-7, 1976.
53. **Gorke W.** The differential diagnosis of congenital analgesia and other diseases with diminished pain perception in childhood. Case report and review. *Neuropediatrics* 12:33-44, 1981.
54. **Colson R H, Watson B W, Fairclough P D, Walker-Smith J A, Campbell C A, Bellamy D & Hinsull S M.** An accurate, long-term, pH-sensitive radio pill for ingestion and implantation. *Biotelem. Patient Monit.* 8:213-27, 1981.
55. **Drexler K E.** Think small. *New Sci.* 117(1605):71, 24 March 1988.