Few therapeutic responses are more dramatic than the response to corticosteroids administered overnight to a drowsy and hemiplegic patient with a cerebral tumor, who next morning is alert with minimal neurological disability, even though this effect may be short lived. Unfortunately, no such dramatic response is seen in patients with ischemic or hemorrhagic stroke; but does this mean that such therapy is totally ineffective? The categorization of cerebral edema by Klatzo and Seitelberger into “cytotoxic” and “vasogenic” holds the key to this therapeutic response.

Cytotoxic, or “intracellular,” edema represents the earliest response to cerebral damage, and whether ischemic or traumatic, is due to the breakdown of cellular ionic pumps causing ingress of water into the cell, and confined within the cellular membrane. The clinical effects and response to corticosteroids of this immediate type of edema is uncertain. Vasogenic edema, occurring hours later, is due to damage to the blood-brain barrier, which becomes “leaky,” allowing extravasation of water, electrolytes, and soon protein into the parenchyma. This produces clinically significant brain swelling, resulting in distortion and herniation of brain and causing neurological disability and death. In brain tumors, the normally tight vascular junctions are pathologically separated, and cellular physiology (such as pinocytosis) is otherwise disturbed, resulting in severe vasogenic edema, which is highly responsive to corticosteroids. This fundamental difference in pathophysiology between the 2 types of lesions may explain the apparent difference in their initial therapeutic response.

There is overwhelming evidence experimentally in a variety of mammalian models that corticosteroids effectively reduce ischemic cerebral edema, both focal and generalized, although the credibility gap needed to extrapolate to the human brain, as always, remains uncertain. In a rather contrived but nevertheless convincing series of experiments, de Courten-Myers et al., using hyperglycemic cats, occluded the middle cerebral arteries for 4 hours, administering high-dose corticosteroids 30 minutes after occlusion. Compared with untreated controls, there was a highly significant, 6-fold difference in the size of the resulting infarcts in favor of the treated group. Paradoxically, there was no significant difference in the acute death rate between the 2 groups of animals, but whether this represents the difference between the sensitivity of response to the drug in cytotoxic versus vasogenic edema must remain speculative. Also, there are other unexplored effects of corticosteroids on the brain, such as the unanticipated but significantly increased cerebral blood flow in the treated group of animals. Effective reduction of cerebral edema after corticosteroids has also been documented in animal models of global ischemia.

Hemorrhagic stroke, in both clinical and experimental trials, has been relatively neglected, probably because of a sense of therapeutic nihilism, but there is a rationale for corticosteroid therapy in the reduction of perihematomal edema. Using a pig model, Wagner et al demonstrated that serum proteins accumulated in the white matter around hematomata (produced by injecting autologous blood into the frontal lobe), resulting in rapid and prolonged cerebral edema. Similarly, CT brain scanning of patients with spontaneous intracerebral hemorrhage showed that the volume of perihematomal edema increased by 75% in the first 24 hours after the event and so should be susceptible to edema-reducing drugs such as corticosteroids.

Early reports of the beneficial effects corticosteroid therapy in inflammatory and neoplastic brain lesions made it a victim of its own success in stroke patients, since a flurry of early clinical trials in anticipation of similar benefits were conducted before enough was known about either the natural history of stroke or correct methodology of clinical trials. Most trials that were conducted were too little or too late, resulting in the premature abandonment of this potential therapeutic avenue. In a recent Cochrane Review, only 7 of 22 published trials of corticosteroids in stroke were acceptable for further analysis, and these comprised woefully inadequate numbers of patients (only 453 in total) with no uniformity of evaluation or assessment, and totally disparate conclusions. No trials have been conducted since 1986. These generally negative results did not deter physicians from the United States or China from administering corticosteroids in stroke patients, however, and 20% of physicians surveyed in both countries reported that they still used them routinely, at least in ischemic stroke.

The Cochrane reviewers concluded that with the available data, they were reluctant to advocate a large-scale therapeutic trial, but that corticosteroid therapy could be factored in as an additional arm of a large trial of a more promising drug. Unfortunately, so far significantly more than 100 neuroprotective trials in acute stroke have proven negative, and it is
unlikely that industry would welcome such a potential con-
 founding factor to a therapeutic trial of their own drug already
costing tens of millions of dollars.
A corticosteroid trial in stroke, with sufficient numbers of
patients and rigorous methodology, will therefore have to
remain a Cinderella until sufficient academic interest and
funding become available.

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Steroids Have No Role in Stroke Therapy
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Steroids are considered as a group of the magic drugs and
have been widely used in neurology for more than 40
years. Theoretically, steroids are immunosuppressive
agents, lessen the damaging effects of vasogenic cerebral edema,
decrease intracranial pressure, and strengthen the blood-brain
barrier. However, these possible benefits have to be weighed
against potentially serious steroid-related side effects such as
immunosuppression and infection, diabetic exacerbation, gastro-
intestinal hemorrhage, and compromised wound healing.

The place of steroids in the management of stroke is still
controversial. As stroke is a heterogeneous condition, it is
therefore unlikely that a single agent would be beneficial in any
treatment plan. Perhaps the only general agreement on the use of
steroids in stroke is where vasculitis is suspected or proven. As
a cause of stroke, vasculitis is very rare (<1% of all strokes), but
treatment with steroids should be started whenever it is suspect-
ed.1 The effectiveness of steroids as one of the options for the
treatment of acute stroke, either hemorrhagic or infarction, has
never been shown. So far only 2 randomized, controlled trials
concerning the use of dexamethasone in primary supratentorial
intracerebral hemorrhage have been reported.2,3

Tellez and Bauer in 1973 did a trial on 40 patients presumed to
have intracerebral hemorrhage and found no beneficial effects of
dexamethasone.2 There were no CT brain scans available at that
period, and 22 patients were later verified to have hemorrhagic
infarction or posterior fossa hemorrhage. Poungvarin et al in 1987
conducted a well-designed double-blind controlled trial of dexam-
ethasone in patients with primary supratentorial intracerebral
hemorrhage confirmed by CT brain scan.4 This study was termin-
nated after the second interim analysis (total of 93 patients) due to
lack of a demonstrated benefit of steroids but showed an over-
whelming number of clinically important adverse effects (ie, local
and systemic infections, gastrointestinal bleeding, and diabetogenic
effects). Recently, Desai and Prasad did a double-blind, random-
ized, placebo-controlled trial of dexamethasone as a pilot project of
26 patients (12 with steroids and 14 placebo) with primary supra-
tentorial intracerebral hemorrhage.5 They found no beneficial effect of
dexamethasone in terms of mortality and morbidity, but the
adverse effects were more in the placebo group (not statistically
significant). In conclusion, evidence-based data on clinical trials of
dexamethasone in primary intracerebral hemorrhage showed no
beneficial effects of steroids.

In the past, steroid treatment had been widely used in acute
intracerebral infarction, yet its value was controversial. Thus Norris
and Hachinski in 1986 did a double-blind controlled trial of
high-dose dexamethasone (480 mg over 12 days) in 113 patients
within 48 hours of onset.5 Fifty-four patients received a high
dose of dexamethasone and 59 matched patients were on placebo.
The 2 groups did not differ significantly in death rate or quality of survivorship. There was a small difference in mortality
between the 2 groups, with marginal therapeutic effect. The
authors concluded that the widespread use of steroids in response
to such a marginal therapeutic gain would expose large numbers of
patients with stroke to more serious hazards of steroid treatment and
convert patients who would otherwise have died into neurovegeta-
tive survivors, which is considered worse than death. High-dose
steroid treatment was ineffective in ischemic stroke, and the data
suggest that further evaluation by a large multicenter trial is not
justified. In 1988, De Reuck et al analyzed 556 ischemic stroke
patients.6 They found 271 patients with steroid treatment and 279
patients without steroids. Comparison of the whole group showed
that the steroid-treated patients had less improvement of their
disability and a higher mortality rate than the nonsteroid group.
However, this study was not a double-blind controlled trial, thus
the patients with steroids were more severe than the placebo group.

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Thus, data from previous clinical trials showed no beneficial effect of steroids for patients with acute cerebral infarction.

For practical purposes, if steroids are beneficial for acute stroke patients, there is no need to perform CT brain scan to differentiate cerebral infarction from hemorrhage. Steroids could be used in any acute stroke patients. To prove this hypothesis, Kumar et al in 1989 performed a clinical trial of dexamethasone in 40 patients with acute stroke (both infarction and hemorrhage) of <48 hours. Twenty-five patients were given dexamethasone and 15 patients placebo. They found no significant difference in mortality between the study and control groups (36% versus 33%). There was also no significant difference in the outcome of patients with cerebral hemorrhage or cerebral infarction whether treated with dexamethasone or not. In 2001, Ogun and Odurose performed a prospective double-blind, placebo-controlled, randomized clinical trial to determine the effectiveness of a short course of high-dose dexamethasone on mortality and neurological recovery in acute stroke patients. Forty patients were eligible for the study (27 were presumed to have hemorrhagic stroke and 13 patients had cerebral infarction). Of the 27 hemorrhagic stroke patients, 15 were treated with 100 mg dexamethasone immediately and 16 mg every 6 hours for 2 days, and 12 patients were given placebo. Of the 13 patients with cerebral infarction, 5 were in the steroid group and 8 in the placebo group. At 1 month, 16 patients (80%) in the dexamethasone group and 17 (85%) in the placebo group had died. In conclusion, this study failed to demonstrate any benefit of a short course of high-dose steroids in improving the mortality of acute stroke patients, and the use of these steroids should be discouraged.

Subarachnoid hemorrhage (SAH) accounts for 7% to 8% of all strokes and leads to early death (1 month) in about 30% to 35%. There is evidence that decreasing plasma volume, hyponatremia, impaired autoregulation of cerebral blood flow, and reactive inflammation are important contributing factors to the development of delayed cerebral ischemia after aneurysmal SAH. Moreover, mineralocorticoid treatment with fluocortisone acetate prevents plasma volume depletion, and glucocorticoid treatment has an anti-inflammatory effect and results in cerebral vasodilatation and improvement of cerebral blood flow after SAH. However, a beneficial effect of steroids on the clinical outcome in patients with SAH has not been proven by any well-conducted clinical trial.

In summary, steroids have a very limited role in stroke therapy. The only definite proven indication of steroids in stroke is in patients with vasculitis. Steroid use in acute stroke, caused by either cerebral infarction or hemorrhage, has been confirmed by several well-controlled clinical trials to be of no benefit. With regard to SAH, it is still debatable whether steroids are beneficial and further studies are necessary to document their benefit.

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Key Words: brain edema ■ corticosteroids ■ dexamethasone ■ stroke, acute

Steroids for Stroke: Another Potential Therapy Discarded Prematurely?

Stephen M. Davis, MD, FRACP; Geoffrey A. Donnan, MD, FRACP

Why do we discard potentially promising therapies so easily? First, the perception that the evidence has been adequately assessed becomes ingrained in the thought processes of everyday practitioners. Second, there is no commercial imperative to drive new trials of therapy. In virtually any modern review of acute stroke therapy, a statement is included that corticosteroids are disproven. However, when the evidence for use of steroids in stroke is examined in more detail, the data seem to be disturbingly sparse. For example, the Cochrane Review of steroids for acute ischemic stroke could identify only 7 trials that met their criteria for evaluation, and these involved only 453 patients. Furthermore, the last of these trials was published in 1986, by Norris and Hachinski. In intracerebral hemorrhage (ICH), there appear to be only 3 randomized control trials targeting ICH alone, involving only 159 patients. However, it should be noted that Poungvarin, one of our protagonists, performed the most rigorous and most often cited study of steroids in ICH in 1987. To date, the amount of evidence is minimal and there have been no recent large

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trials. Methodological problems also include long time windows, uncertainty about dose, protracted steroid treatment, and lack of rigorous monitoring and correction of potential steroid side effects, particularly hyperglycemia.

The theoretical constructs involved here are important, as outlined by Norris. He nicely draws attention to the important differences between vasogenic and cytotoxic edema and their temporal relationships. Practicing clinicians would be well aware that the edema surrounding ICH, commonly seen on CT and MR images, includes vasogenic as well as cytotoxic components. In ICH, the perihematomal edema volume substantially increases in the first 24 hours after onset and is independently predictive of functional outcome. Hence, it would seem more logical to study the effects of steroids in cases of hemorrhage rather than infarction, where it is generally considered that cytotoxic edema predominates.

Modern trial principles for any re-evaluation of steroids in stroke would require administration of therapy during an earlier time window, use of high-dose intravenous steroids (such as methylprednisolone), a shorter duration of therapy to avoid potential side effects, and adequate sample size. Adverse effects of steroid therapy, such as hyperglycemia, infections, and gastrointestinal hemorrhage, have offset any trend to improvement in ICH in previous trials. These would need to be considered in trial design. For example, with the modern understanding of the adverse effects of hyperglycemia in acute stroke, rigorous glycemic monitoring and insulin therapy would be required. Both of our protagonists have published widely quoted negative studies concerning steroids in stroke. Norris points out that steroid use remains prevalent, nonetheless, in many countries. This is an ideal scenario for a high-quality investigator-driven trial to be generated. Clearly, this has no commercial attraction, as is the case with many potentially promising but prematurely discarded therapies. We will watch with interest.

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