Demeclocycline in the treatment of the syndrome of inappropriate antidiuretic hormone release: with measurement of plasma ADH

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Summary
A patient with the syndrome of inappropriate antidiuretic hormone release (SIADH) following head injury and meningitis was studied during treatment with demeclocycline, a drug known to produce a reversible nephrogenic diabetes insipidus. No changes were observed during six days of demeclocycline 1200 mg/24 hr but urine output increased significantly, with the production of a dilute urine, when the dose was increased to 2400 mg/24 hr. The patient lost weight, and all biochemical features of the syndrome were rapidly corrected despite an unchanged fluid intake and despite the persistence of high plasma levels of ADH. The rise in serum sodium was accompanied by mild sodium retention, as measured by external balance and exchangeable sodium.

A complication of treatment was the development of acute renal failure possibly induced by a nephrotoxic effect of high circulating levels of demeclocycline. On stopping demeclocycline renal function returned to normal and, after some delay, SIADH returned, and was still present 9 months after initial presentation. This confirms earlier reports of the efficacy of demeclocycline in SIADH; but the authors advise caution against increasing the dose above 1200 mg/24 hr.

Introduction
Fluid restriction, the conventional therapy for the syndrome of inappropriate antidiuretic hormone secretion (SIADH) (Barter and Schwartz, 1967) can be irksome and requires close supervision of fluid intake. Both lithium carbonate (Singer, Rotenberg and Puschett, 1972) and demeclocycline (White and Feiner, 1975; De Troyer and Demanet, 1975; Cherrill et al., 1975; Cledes, Clavier and Kerbrat, 1976; Perks, Mohr and Liversedge, 1976) have been shown to be effective in the treatment of SIADH in a small number of patients. It has been possible to study, in detail, the effects of demeclocycline on fluid and electrolyte balance in a patient with SIADH following head injury and meningitis, together with serial measurements of plasma ADH.

Case history
A 64-year-old male was admitted to hospital, 4 days following a head injury, with a story of progressive confusion. A clinical diagnosis of meningitis was confirmed by the finding of an increased cell count in the cerebrospinal fluid with pneumococci on direct film and grown on culture. He was started on penicillin and sulphadimidine and 12 days later was much improved. On admission his serum sodium had been 139 mmol/l with a blood urea of 51 mmol/l and 12 days later 133 mmol/l and 2.9 mmol/l respectively. Skull radiology revealed an occipital fracture but chest X-rays were persistently normal. Seventeen days after admission he was discharged although his serum sodium at that time was 128 mmol/l. He was re-admitted one week later grossly confused with no focal neurological signs. A repeat lumbar puncture was normal but his serum sodium had fallen to 112 mmol/l. On the day after admission, serum sodium was 108 mmol/l with a plasma osmolality of 219 mosmol/kg with a concurrent urine osmolality of 473 mosmol/kg. Plasma ADH was elevated at 9 pg/ml (normal range 4–8 pg/ml); clearly inappropriate for the plasma osmolality. Fluid restriction resulted in a rise of serum sodium to 136 mmol/l with a parallel improvement in clinical state. He was discharged from hospital with advice to restrict his fluid intake but serum sodium fell again to 126 mmol/l. He was re-admitted 3 months after his initial presentation for assessment of the effects of demeclocycline.

Special studies
The patient was admitted to a metabolic ward and placed on a fixed normal intake of sodium (133 mmol/24 hr) and potassium (53 mmol/24 hr). Fluid intake was arbitrarily fixed at 2000 ml/24 hr (a volume designed to ensure the presence of SIADH). During
of demeclocycline were measured using gas-liquid chromatography (quoted antibacterial range 3-5 μg/ml).

Results of special studies
Fluid balance (Fig. 1)

During the initial run-in period, urine output was fairly constant and averaged 1333 ml/24 hr. The mean early morning urine osmolality was 660 mosmol/kg. During the first day of demeclocycline therapy urine output increased to 2200 ml although the osmolality was not measured. Thereafter, urine output fell, giving a mean daily output of 1590 ml during the 6 days of the lower dose of demeclocycline. The mean early morning urine osmolality during this period was 600 mosmol/kg. On increasing the dose of demeclocycline to 2400 mg/24 hr a diuresis occurred with a daily urine output averaging 2363 ml (osmolality 266 mosmol/kg). As fluid intake and ambient temperature were constant, this represents a true fluid loss and was accompanied by a dramatic fall in weight (Fig. 2).

Sodium balance (Fig. 2 and 3)

Serum sodium remained low during the run-in period and during the first 6 days of demeclocycline treatment. Thereafter serum sodium and plasma osmolality rose rapidly to normal (Fig. 2). During the run-in period exchangeable sodium was 2860 mmol and exchangeable potassium 2846 mmol. At the end of the study exchangeable sodium had increased to 2957 mmol and potassium had remained unchanged at 2848 mmol. Urine samples for electrolyte measurement were lost during the first 3 days of the study but the net balance during the remaining 3 days of the run-in period and the first 6 days of demeclocycline therapy was constant, averaging an apparent positive balance of 53 and
51 mmol/24 hr respectively. During the last 6 days of the study there was initially sodium retention so that the average positive balance was 68 mmol/24 hr: a net increase of 16 mmol/day over the earlier periods. This represents a total gain of 96 mmol over the 6-day period (tallying well with exchangeable sodium). There was no significant change in either serum potassium or external potassium balance.

**Antidiuretic hormone**

With the exception of one value of 3.6 pg/ml on the first day of demeclocycline therapy ADH levels remained high throughout the study (Fig. 2) with a probable slight increase at the end of the study.

**Renal function**

During the phase of acute diuresis, renal function deteriorated rapidly, creatinine clearance falling from a mean of 123 ml/min during the first 12 days to 34 ml/min at the end of the study when demeclocycline therapy was discontinued (Fig. 2).

**Blood levels of demeclocycline**

Plasma demeclocycline increased rapidly during the second period of administration of the drug from 4.5 μg/ml at the end of the 1200 mg period to a peak of 11.9 μg/ml (Fig. 2).

**Subsequent course**

The patient rapidly recovered following the cessation of demeclocycline and over the following 2 weeks blood urea urea fell to 3 mmol/l and creatinine clearance increased to 98 ml/min. Serum sodium remained above 135 mmol/l for approximately two months and then gradually fell over a period of three months to stabilize at about 126 mmol/l with a plasma osmolality of 260 mosmol/kg and urine osmolality of 570 mosmol/kg. Despite this, he has remained well with no complaints and chest X-ray has been repeatedly negative. His migration abroad has precluded further study.

**Discussion**

SIADH in this man was related to head injury and subsequent meningitis and this seems the likely aetiology (Barter and Schwartz, 1967). The duration of the syndrome is rather long, however, and the possibility of an occult neoplasm must continually be borne in mind. Fluid restriction proved difficult and another form of treatment was clearly desirable.

Demeclocycline produces a predictable, reversible and dose-dependent nephrogenic diabetes insipidus (Singer and Rotenberg, 1973) unlike lithium carbonate whose effect on renal function is variable (Forrest et al., 1974; Padfield et al., 1977). It has been claimed that while tetracyclines in general (Shils, 1963) and outdated tetracyclines in particular (Gross, 1963) can be nephrotoxic the renal effects of demeclocycline are confined to an impairment of concentrating ability (Wilson et al., 1973). Castell and Sparks (1965) were the first to describe this peculiar property of demeclocycline, and their initial observations have since been confirmed (Singer and Rotenberg, 1973; Wilson et al., 1973; Maxon and Rutsky, 1973; Hayek and Ramirez,
Plasma levels of ADH vary widely in SIADH and extremely high values are not always seen (Padfield et al., 1976). The patient clearly had an inappropriately high plasma ADH at a time when his plasma was dilute. With the exception of one value during the study, ADH levels remained high throughout, clearly showing that correction of the syndrome was not due to a spontaneous recovery. There was a slight tendency for ADH to rise towards the end of the period of treatment and the significance of this observation has already been discussed (Padfield et al., 1976).

In conclusion, the effectiveness of demeclocycline in correcting the biochemical abnormalities of SIADH in the presence of high circulating levels of ADH has been demonstrated. In the dosage used in this study there was possible evidence of nephrotoxicity and the future use of the drug will need to be confined to smaller doses. Clearly, demeclocycline represents an important advance in the treatment of syndrome of inappropriate antidiuretic hormone release.

References
Case reports


