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Case Report

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Summary: We present an unusual case of diabetes insipidus occurring after selective embolization of 50% dextrose and pure ethanol into an enlarged left meningohypophyseal trunk (MHT) supplying a dural carotid cavernous fistula. The inferior hypophyseal artery was not opacified during the selective preembolization MHT injection; however, diabetes insipidus developed abruptly a few hours after the procedure. The patient required intranasal 1-deamino-(8-D-arginine)-vasopressin for approximately 3 months, after which his symptoms resolved. The hazards of using liquid embolic agents, especially ethanol, in the cavernous branches of the internal carotid artery should always be borne in mind.

We report the onset of diabetes insipidus following embolization (with pure ethanol and 50% dextrose solution) of a meningohypophyseal trunk (MHT) supplying an indirect carotid cavernous fistula (CCF). Embolic causes of diabetes insipidus are rare (1) and to our knowledge this has not been reported previously. The anatomic and pathophysiologic considerations are reviewed.

Case Report

A 59-year-old man presented with a 9-month history of increasing hyperemia of the right eye. In the 3 months preceding presentation, the right eye had become proptotic with consequent diplopia and a subjective decrease in visual acuity. At presentation, the eye was markedly proptotic with scleral hyperemia and chemosis. There was mild mechanical restriction of ocular movement in all directions. Uncorrected visual acuity in the right eye was 20/50 and 20/30 in the left. There was no intracranial bruit.

A CT scan of the head showed a dilated right superior ophthalmic vein. A subsequent cerebral angiogram showed an indirect right CCF supplied by both MHTs, both middle meningeal arteries, and the right artery of the foramen rotundum. The left MHT represented the dominant arterial supply. Arterial blood entered a partially thrombosed right cavernous sinus with exocranial outflow exclusively via the right superior ophthalmic vein (Fig 1A and B). The right inferior petrosal sinus was thrombosed, and there was no cortical venous drainage.

Endovascular treatment was performed initially using a transvenous approach. The right cavernous sinus was accessed with a microcatheter and microguidewire via the thrombosed right inferior petrosal sinus; however, the fistulous compartment could not be located, thereby necessitating transarterial embolization. Because the contribution to the fistula of both middle meningeal arteries was insignificant, they were not embolized. The right artery of the foramen rotundum was selectively catheterized using a rapid transit microcatheter (Cordis Endovascular, Miami Lakes, FL) and successfully embolized using 2 mL of opacified 50% dextrose solution.

The patient returned to the neuroangiography suite 2 days later, at which time an enlarged left MHT (Fig 1C and D) was selectively catheterized using a Prowler 0.014-inch microcatheter (Cordis Endovascular) in combination with a Transend 0.014-inch guidewire (Scimed Life Systems, Maple Grove, MN). Embolization of the pedicle was initially performed using 3 mL of 50% dextrose solution opacified with metrizamide powder (Amipaque, Nycomed, Princeton, NY). However, approximately 20 minutes after embolization, the angiographic appearance was unchanged, so 0.5 mL of unopacified pure ethanol was then injected into the pedicle, resulting, after a few minutes, in its occlusion. In light of this development, the contralateral MHT, which also supplied the fistula, was not embolized because of the perceived risk of causing diabetes insipidus (possibly permanently) if both MHTs were obliterated.

Shortly after the patient returned to the ward, acute-onset diabetes insipidus developed, with a precipitous rise in urine output (up to 1800 mL/h) and a decrease in urine-specific gravity (<1.005). There was no clinical evidence of attendant anterior pituitary lobe dysfunction or cranial nerve palsy. The serum sodium level peaked at 156 mmol/L the following morning. Intravenous therapy with 1-deamino-(8-D-arginine)-vasopressin (dDAVP) was instituted, resulting in clinical improvement and stabilization. The patient was discharged home 9 days later on 100 μg of intranasal dDAVP twice a day. One month later, the dDAVP requirement had decreased to 100 μg every second day and, by 3 months, ceased completely. Five months after the procedure, the patient was well, with no symptoms of diabetes insipidus. His visual symptoms had improved substantially, with near complete resolution of the right eye proptosis, hyperemia, and diplopia, with visual acuity in the right eye improving to 20/30.

Discussion

Vasopressin or antidiuretic hormone (ADH) is an octapeptide synthesized in the supraoptic and paraventricular nuclei of the hypothalamus and secreted, after neuronal transport along the pituitary stalk, from axon terminals in the posterior pituitary gland. It is the hormone responsible for osmotic

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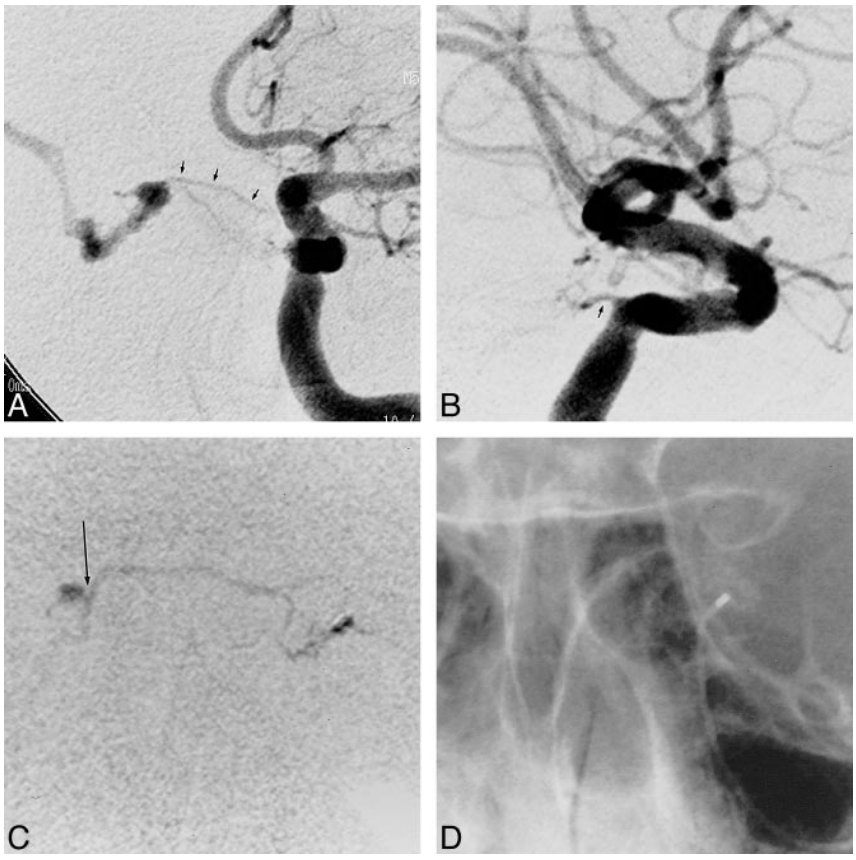


FIG 1. 59-year-old man with hyperemia, proptosis, diplopia, and decrease in visual acuity of the right eye.

A and *B,* Anteroposterior (*A*) and lateral (*B*) views of left ICA injection show an enlarged left MHT (*arrow, B*), the dorsal meningeal branch of which courses across the midline to supply the CCF (*arrows, A*).

C and *D,* Anteroposterior views of the selective left MHT injection, subtracted (*C*) and unsubtracted (*D*). The point of fistularization is situated at the left posterior cavernous sinus (*arrow, C*). Note the catheter tip projects laterally.

homeostasis in humans. It acts on the cells of the renal collecting duct to increase free water absorption and produce a hypertonic urine (2). Diabetes insipidus is an endocrinologic syndrome characterized by the passage of large volumes of dilute urine. This results in a free water deficit, which, if not replenished (there is usually a compensatory polydipsia), leads to dehydration and serum hypernatremia (hypertonicity). There are four clinical subtypes depending on the etiologic mechanism. The most frequent is impaired ADH secretion, otherwise referred to as neurogenic or central diabetes insipidus. A second type is renal resistance to ADH, also known as nephrogenic diabetes insipidus. Dipsogenic diabetes insipidus, a third category, results from excessive water intake; and the fourth type, gestational diabetes insipidus, is seen in pregnancy, partly as a result of increased metabolic clearance of ADH (3). Central diabetes insipidus is further subdivided into partial or severe, depending on the residual ADH secretory capacity. A complete deficiency of ADH is rare, as even in patients with a severe familial form of central diabetes insipidus, small amounts of the hormone are usually detectable in the urine (4). In the setting of hypernatremia, nonspecific neurologic signs and symptoms, such as restlessness, irritability, lethargy, myoclonus, and hyperreflexia, are the most common clinical manifestations, resulting primarily from intracellular neural dehydration. Intracranial hemorrhage, including subdural hematoma, believed to be due to brain shrinkage with consequent traction on the superficial cerebral veins and dural venous sinuses, has been reported in children (5, 6).

There are numerous causes (including iatrogenic) of central type diabetes insipidus: to our knowledge, selective embolization of the MHT as an antecedent has not been previously reported. In fact, selective hypothalamic-pituitary dysfunction is rare in embolic disease of any kind (1). In 1950, Sancetta and Zimmerman (7) reported the first case of diabetes insipidus (transient) complicating bacterial endocarditis, postulating an embolic origin and noting, ''As these affections often cause embolic occlusions of the cerebral vessels, it is indeed noteworthy that diabetes insipidus is not more frequently observed.'' An embolic pathogenesis may have also been responsible in a case of diabetes insipidus accompanying thrombotic thrombocytopenic purpura (8). A previous pathologic report of 49 cases of thrombocytopenic purpura observed that the neurohypophysis frequently harbors the characteristic microvascular lesion (9), and yet attendant clinical diabetes insipidus is uncommon. The first report of clinical diabetes insipidus complicating systemic fat embolism appeared in 1970 (10). Sevitt (11) had previously noted fat emboli and hemorrhages in the pituitary glands of patients who died of systemic fat embolism, noting a greater frequency of lesions in the posterior gland, a fact he attributed to the large flow through this region derived from the inferior hypophyseal artery

(IHA). He predicted that if there were to be a disturbance of ADH secretion it would not likely be permanent, given his observation of no substantial parenchymal necrosis of the posterior lobe, even in cases with a high concentration of lesions (fat emboli and small hemorrhages). In accordance with this prediction, diabetes insipidus in our patient was self-limited despite the fact that liquid sclerosing agents, such as used in this case, theoretically provide a deeper and more comprehensive penetration of the microvasculature than do particulate emboli (see later discussion). More recently (1997), a case report documenting sudden onset of central diabetes insipidus in a patient with known aortic valve stenosis and transient ischemic attacks postulated an embolic origin and furthermore suggested that some cases of idiopathic central diabetes insipidus may be secondary to atheroma (cholesterol)–related emboli (12).

The IHA represents the principal arterial supply to the neurohypophysis and is the largest artery supplying the pituitary gland. As it reaches the pituitary body, it divides into superior and inferior branches and joins with its counterpart from the opposite side to form an anastomotic circle (13). It was Luschka in 1860 who first identified the IHA in humans (14). In 1953, McConnell (15) published an important article describing in detail the arterial supply of the human pituitary gland. She described a small arterial trunk arising from the first short vertical course of the cavernous portion of the internal carotid artery (ICA) (C5 segment) just before it bends to a horizontal segment that, after a short distance, divides into three branches, the largest of which is the IHA (15). McConnell found this arrangement to be remarkably constant, although not invariable. Eleven years later, Parkinson (16) christened this diminutive vessel the meningohypophyseal artery or trunk. In his study, which examined over 200 cadaveric specimens, he found the existence of a single trunk, which trifurcated into three branches; namely, the inferior hypophyseal, the dorsal meningeal artery, and the tentorial artery, originally characterized by Bernasconi and Cassinari (17) as a constant finding without exception or variation (Fig 2). In this seminal paper, Parkinson also describes the caliber of the MHT as being, in most instances, equal to that of the ophthalmic artery in the same patient, an observation that would at best seem doubtful to a modern neuroradiologist.

The invariable existence of a single MHT (or at least a single trunk in the vast majority of cases) is somewhat controversial and has been regarded as an oversimplification by some authors, particularly Lausjaunias et al, who suggested that the various collateral vessels of the C5 segment most frequently arise from the ICA independently of one another (18, 19). Other authors have, however, concurred with Parkinson's findings (20, 21). It seems likely that some variability in the presence and distribution of the MHT does indeed exist; however, the traditional description by Parkinson remains widely

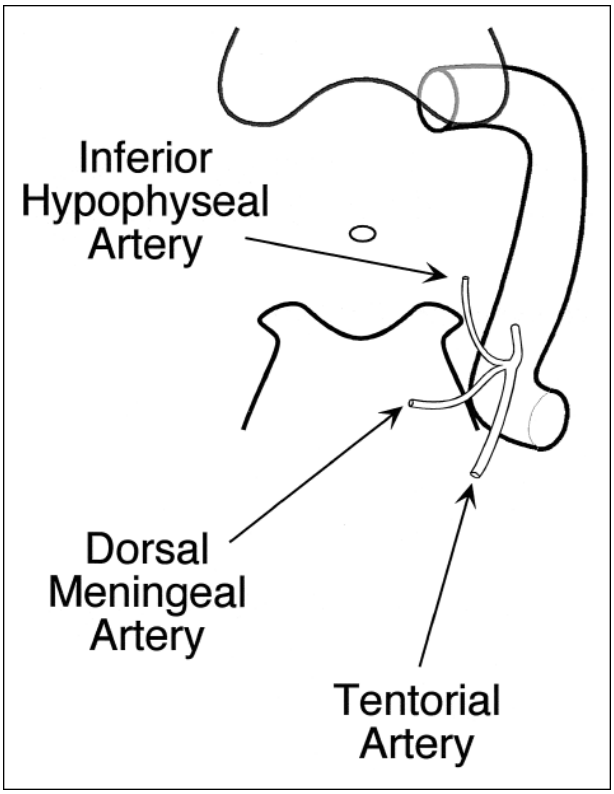


FIG 2. Schematic representation of the MHT and its three principal branches (according to Parkinson). The IHA is the largest branch.

used, albeit with the recognition of the potential for diversity. In 1987, Tran-Dinh (22) provided an excellent historical review of the anatomic literature concerning this region, and suggested a simple modified nomenclature for the cavernous branches of the ICA.

The radiologic characteristics of the MHT were well described by Pribram et al in 1966 (18); however, this account preceded the era of microcatheters and superselective catheterization techniques. Interpretation of the selective injection into the left MHT in our case is influenced by the knowledge that this branch supplies a dural CCF. An enlarged dorsal meningeal artery anastomosing with its opposite counterpart supplies the CCF, with the point of fistularization at the posterior right cavernous sinus clearly identifiable (Fig 1C and D). The IHA and tentorial artery did not opacify during the superselective MHT injection and hence embolization was considered feasible because the embolic agent would preferentially flow to the fistula rather than into the normal branches (IHA and tentorial arteries). However, it is important to recognize that as flow to the fistula is decreased, the likelihood of embolization into the IHA and tentorial branches increases. The efficacy and safety of embolization of ICA cavernous branches in the treatment of dural fistulas have been reported by Halbach et al (23). In our case, after embolization with 3 mL of 50% dextrose solution, there did not appear to be

appreciable change in the flow to the fistula; however, mild contrast staining (possibly related to small branches of the IHA) was noted on a blank roadmap image. Following this, 0.5 mL of unopacified pure ethanol was injected into the MHT, promptly resulting in occlusion at its origin.

The respective contributions of the dextrose and ethanol in the pathogenesis of the diabetes insipidus can only be postulated. Of note, there was no evidence of oculomotor, trochlear, trigeminal, or abducens nerve dysfunction (all of these cranial nerves may receive arterial supply from the MHT). Hypertonic solutions, such as 50% dextrose, probably cause endothelial cell dehydration and death through osmosis, their destructive power being proportional to their osmotic concentration. Maximal effect occurs in small, slow-flow vessels at or near the site of injection. In contrast, detergent sclerosing solutions can cause sclerosis for 5 to 10 cm along the injected vessel (24). Ethanol causes thrombosis by a variety of mechanisms, including dehydrating endothelial cells, denuding and segmentally fracturing the vessel wall, and denaturing blood proteins. When embolized into normal tissue, ethanol can lead to complete and permanent devitalization (necrosis), as it is capable of penetration to the capillary bed level. Following vascular injury, recanalization and neovascular recruitment are less frequent than with other embolic agents (25, 26). The possibilities in our case are that neurohypophyseal damage was instigated by the dextrose (therefore allowing the possibility of future recanalization), that the ethanol did not damage enough of the neurohypophysis to result in permanent hyposecretion (the contralateral MHT was not embolized and the anastomotic circle may afford a protective effect), or a combination of these factors.

Conclusion

Our experience underscores the importance, when selectively embolizing small vessels with liquid agents (particularly ethanol), of using small aliquots (only 0.5 mL was used in this case) followed by a pause of at least 10 to 15 minutes before rechecking vessel flow with contrast and proceeding to further embolization if required.

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