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The MR Appearance of Syringomyelia: New Observations

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Fifty-eight patients with spinal cord cavities were studied with MR imaging. Patients were separated into four groups, and the appearance of the cavities were compared. There were 24 patients (41.4%) with communicating syringomyelia (associated with the Chiari I malformation). Sixteen patients (27.6%) had posttraumatic syringomyelia, nine patients (15.5%) had associated tumors, and nine patients (15.5%) had idiopathic syringomyelia. The characteristics of each syrinx, the spinal cord, and the appearance of the cerebellar tonsils were analyzed on T2- and T1-weighted images. There is a striking similarity in the appearance of many syrinx cavities regardless of the cause. Characteristics that were found in some patients in every group included areas of increased intensity on T2-weighted images, the presence of the CSF flow-void sign (CFVS) in the syrinx cavity, eccentric cavities, "beaded" cavities, and cord enlargement. Tonsillar ectopia alone does not indicate that a syrinx is of the "communicating" type, since it was present in two of 16 patients (13%) with trauma and in two of five patients (40%) with tumors. T1-weighted images were most useful in evaluating the anatomic characteristics of the syrinx and the cerebellar tonsils. Most syrinx cavities involved the cervicothoracic junction. The average length was between five and nine vertebral segments (depending on category) but varied between one and 20 vertebral segments. T2-weighted images revealed areas of increased intensity in the spinal cord in 13 patients without tumors. Two of these cases were shown to represent gliosis on histopathologic review. The CFVS was present in the syrinx cavities of 23 patients (40%), probably reflecting pulsatile movements of the syrinx fluid. It has been proposed that such movements are a cause of syrinx propagation, and the observation of the CFVS may have prognostic significance. The development and progression of the CFVS was documented in serial MR examinations in one patient over an 18-month period. The theories of syrinx development and propagation are reviewed.

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Syringomyelia is a chronic disorder involving the spinal cord. Pathologically, it is characterized by the presence of longitudinally oriented cavities and gliosis. The term "hydromyelia" has been used to describe the appearance of dilatation of the central canal of the spinal cord while the term "syringomyelia" has been reserved for cavities independent of the central canal [1]. From a practical viewpoint, it is impossible to differentiate most cases of true hydromyelia from those of true syringomyelia. Consequently, recent literature tends to unite the two terms (syringohydromyelia) [2, 3] or to use the terms "syringomyelia" or "syrinx," [4-6] in a generic sense to refer to the spectrum of disease that is involved without implying endorsement of a specific pathogenetic hypothesis. We will follow that trend in this report.

Previous reports have emphasized the usefulness of MR imaging in evaluating patients with suspected syringomyelia [7-9]. In this paper we report our observations of the syrinx cavities and cerebellar tonsils in patients with uncomplicated syringomyelia (communicating syringomyelia), traumatic syringomyelia, idiopathic syringomyelia, and syringomyelia associated with tumors.

Subjects and Methods

Eighty MR examinations of 58 patients with cavities within the spinal cord were evaluated retrospectively. All but two cases were selected from our combined files of approximately 5000 MR examinations. There were 33 men and 25 women ranging in age from 8 to 68 years, with an average age of 38 years. The spinal cord cavities were classified into four groups on the basis of clinical and radiologic criteria. The groups included: syringomyelia with tumor, traumatic syringomyelia, "communicating" syringomyelia (associated with Chiari I malformation), and idiopathic syringomyelia. Patients with the Chiari type I malformation who did not have a history of trauma and did not have a spinal neoplasm were placed in the "communicating" syringomyelia group.

The characteristics of the spinal cord, syrinx, and cerebellar tonsils were recorded. The selected syrinx characteristics included length (in vertebral segments), diameter of the cavity (in millimeters), intensity (specifically, presence of increased intensity on T2-weighted sequences when compared with normal spinal cord tissue), and presence of the CSF flow-void sign (CFVS) [10] in the syrinx cavity. The presence of spinal cord atrophy or enlargement was determined by inspection, and determination of central or eccentric position of cavities was made when possible. All measurements were made from the hard-copy images using calipers and the relative MR scale generated on each image. Measurements were made to the nearest millimeter. The shortest distance between the tip of the tonsil and the foramen magnum line was measured to find the extent of tonsillar ectopia [11].

MR examinations of 51 patients were performed on a 0.5-T whole-body superconductive magnet (Vista-MR, Picker International Corp.). Seven patients were studied on a 1.5-T, whole-body, superconductive unit (Teslacon, Technicare) operating initially at 0.6 T (three patients) and subsequently at 1.5 T (four patients). Standard, manufacturer-provided, single-echo spin-echo (SE) sequences were performed. Data was typically acquired with either 256 or 128 complex samples/views, 256 views, and four excitations using the 2-dimensional Fourier transform method. A 256×256 or 128×256 matrix was used. The field of view for these examinations was 30 cm for at least one sagittal sequence in all cases, although variable field diameters were also used during many examinations. T2-weighted sequences were done with a TE of 60, 80, 100, or 120 msec and a TR of 1500–3000 msec. T1-weighted sequences employed a TE of 26–40 msec with a TR of 500–800 msec. Intermediate sequences were occasionally used if time permitted. Sagittal T1-weighted images were obtained in all patients; sagittal T2-weighted images were obtained in 49 patients. The section thickness was 5 mm for all T1-weighted examinations. T2-weighted and intermediate sequences were obtained using either 5-mm or 10-mm section thicknesses. The patients

were supine during the examination. Surface coils were used in the evaluation of 40 patients, frequently in conjunction with the head coil or body coil.

Results

The results are presented by category. A comparative summary of the findings in each category is provided in Table 1. The table also gives the number of cases in which areas of cord enlargement or atrophy were present, the number of cases in which eccentric cavities were identified at least at one level, and the presence of a "beaded" shape (these latter features are not specifically detailed in the text). A stacked bar graph showing the number of cases involving each vertebral level appears in Figure 1. Figures 2, 3, 4, and 5 portray the length and location of each syrinx according to category. Most syrinx cavities involved the cervical and upper thoracic spine. Certain observations could not be made in some cases because the necessary images had not been obtained or because surgery had distorted the normal landmarks.

Communicating Syringomyelia

This group contained 24 patients (41%), including 13 women and 11 men, ranging in age from 16 to 68 years. The average age was 39 years. In six of 24 cases, surgical treatment of the syrinx cavity had been performed before MR imaging.

The syrinx cavity varied in length from one to 17 vertebral segments. The average known length was seven to eight vertebral segments. The length and locations of the cavities are depicted in Figure 2. The incidence of cord enlargement, atrophy, and eccentric cavitations is given in Table 1. In five of 24 patients, the syrinx involved the cervical segments but the lower extent was not determined because the remainder of the spine was not examined. The diameter of the syrinx cavities varied from 2 to 15 mm with an average of 5.5 mm.

T2-weighted images showed areas of abnormally increased intensity in the spinal cord at the rostral end of the syrinx in six patients. One patient (44, F) had a very prominent area of increased intensity in the cervical spinal cord around the upper margin of the syrinx cavity and extending rostrally farther than the cavity (Fig. 6) There were 12 mm of tonsillar hernia-

TABLE 1: Comparison of Characteristics of Syringomyelia by Classification Type

	Communicating (n = 24)	Trauma (n = 16)	Tumor (n = 9)	Idiopathic (n = 9)
Areas of increased T2	6/18 (33%)	4/16 (25%)	9 (100%)	3/6 (50%)
CFVS in syrinx	13/16 (81%)	4/14 (29%)	2/9 (22%)	4/6 (67%)
Cord enlargement	12/24 (50%)	12/16 (75%)	8/9 (89%)	2/8 (25%)
Cord atrophy	4/24 (16%)	4/16 (25%)	1/9 (11%)	0
Eccentric cavity	11/16 (69%)	3/3 (100%)	2/4 (50%)	2/6 (33%)
Lobulated cavity shape	9/24 (38%)	3/16 (19%)	1/9 (11%)	2/8 (25%)
Cavity length (spinal segments)	1–17 (avg = 7.5)	1–19 (avg = 8.5)	1–20 (avg = 5.7)	2–16 (avg = 6.1)
Maximum cavity diameter	2–15 mm (avg = 5.5 mm)	3–15 mm (avg = 6.6 mm)	2–12 mm (avg = 7.3 mm)	2–9 mm (avg = 5.7 mm)
Tonsillar ectopia	23/23 (100%)	2/16 (13%)	2/5 (40%)	0

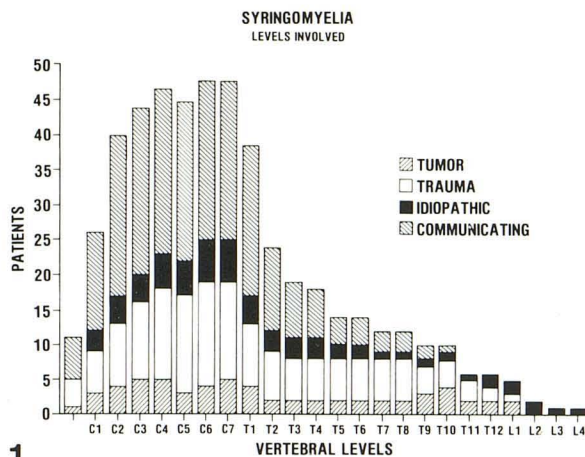


Fig. 1.—Stacked bar graph showing number of cases involving each vertebral level. Note greater number of cases involving cervicothoracic area. Length of each syrinx is shown in Figures 2–5.

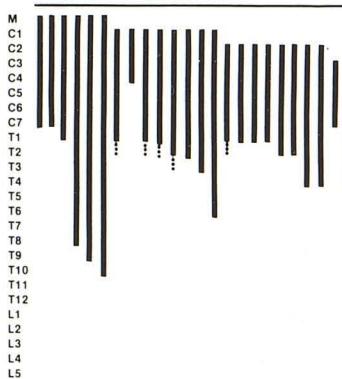
Fig. 2.—Length and extent of involvement is shown for patients with "communicating" syringomyelia. Dotted lines indicate that full extent of syrinx was not determined.

Fig. 3.—Length and extent of involvement is shown for patients with traumatic syringomyelia. Dotted lines indicate that full extent of syrinx was not determined.

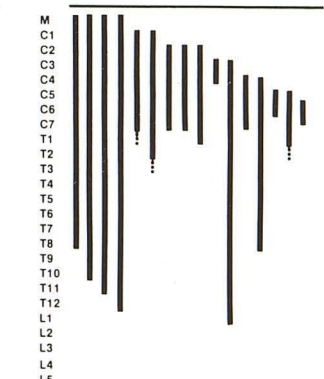
Fig. 4.—Length and extent of involvement is shown for patients with syringomyelia associated with tumors. Dotted lines indicate that full extent of syrinx was not determined.

Fig. 5.—Length and extent of involvement is shown for patients with idiopathic syringomyelia. Dotted lines indicate that full extent of syrinx was not determined. Two patients with spinal cord tethering had abnormally low cord positions.

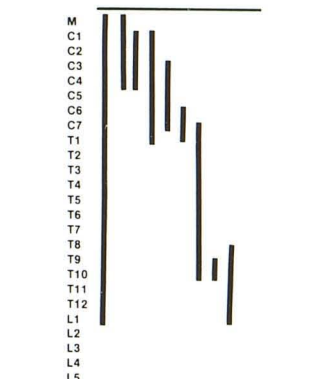
**LOCATION AND LENGTH OF CAVITIES
IN COMMUNICATING SYRINGOMYELIA**



**LOCATION AND LENGTH OF CAVITIES
IN TRAUMATIC SYRINGOMYELIA**



**LOCATION AND LENGTH OF CAVITIES
IN SYRINGOMYELIA WITH TUMORS**



**LOCATION AND LENGTH OF CAVITIES
IN IDIOPATHIC SYRINGOMYELIA**

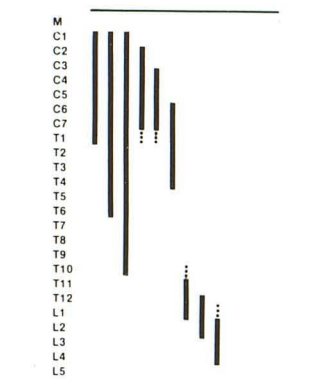
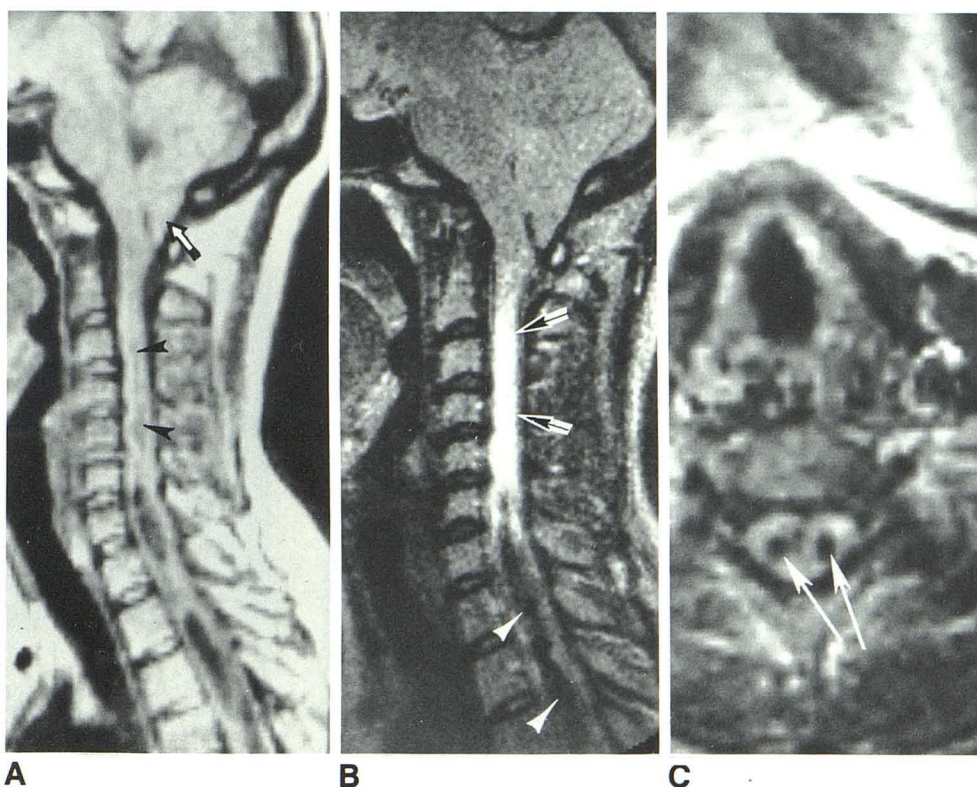


Fig. 6.—44-year-old woman with Chiari I malformation and syringomyelia. **A**, SE 800/40. Note "pointed" cerebellar tonsils 12 mm below foramen magnum (arrow). Syrinx cavity tapers rostrally (arrowheads). **B**, SE 2000/80. Prominent area of increased intensity (arrows) represents gliosis (pathologically proven). Area of decreased intensity in syrinx is CFVS (arrowheads). **C**, SE 1000/40. Transaxial image at C6 level. Note eccentric cavities (arrows).



tion. This study came early in our experience and because of the prominent increased intensity, a spinal cord neoplasm was suspected. A biopsy was performed and officially interpreted as a grade II astrocytoma. Later, at our request, the tissue was reviewed by the Armed Forces Institute of Pathology and interpreted as gliotic tissue without evidence of astrocytoma.

In 16 of 24 patients, T2-weighted SE sequences were available for evaluation of the CFVS in the syrinx cavity. The CFVS was present in 13 of these 16 patients (Figs. 6 and 7). In these 13 patients, the syrinx cavities extended an average of nine to 10 vertebral segments, and the average cavity diameter was 7.4 mm (range, 2–15 mm). In five of the 13 patients with the syrinx CFVS, the sign was seen throughout the entire length of the syrinx (average, eight segments). In the other eight of 13 patients the CFVS was seen better in the thoracic portion of the cavity, or the CFVS was discontinuous. Three patients with adequate T2-weighted examinations had no evidence of the CFVS in the syrinx cavity. In two of these patients the syrinx involved the entire cervical canal but the cavity diameter was only 3 mm. In the other patient the syrinx extended only two segments and was only 2 mm in diameter. Eight patients were evaluated with T1-weighted or proton-density SE sequences only and the presence of the syrinx CFVS could not be reliably determined.

The position of the cerebellar tonsils could be determined in all but one patient. Tonsillar position varied from 1 to 27

mm below the foramen magnum. The average position was 8–9 mm below the foramen magnum. The tonsils appeared variably compressed or pointed (Figs. 6 and 7) in all cases and also varied markedly in size in different patients.

Traumatic Syringomyelia

Sixteen patients (28%) had syringomyelic cavities that were clinically determined to be posttraumatic in origin. The group was composed of 12 men and four women, ranging in age from 19 to 58 years with an average age of 41 years.

Surgery was performed before our evaluation in 12 of 16 patients. Nine patients had cervicothoracic syrinx cavities, and seven patients had cavities apparently limited to the cervical cord; however, full thoracic MR was not performed in five of these seven patients. The lengths of the cavities ranged from one vertebral segment to total spinal cord involvement. The average known length was eight to nine vertebral segments. (The length and location of the cavities are given in Figure 3.) The diameter of the syrinx cavities varied from 3 to 15 mm, averaging 6 mm.

T2-weighted images were available in 14 of 16 patients. In four patients these images showed an adjacent area of increased intensity within the spinal cord. These areas were thought to represent gliosis, edema, or myelomalacia. In one of the patients with a focal ovoid cyst, the cyst contents had a higher intensity signal than did CSF in the basilar subarach-

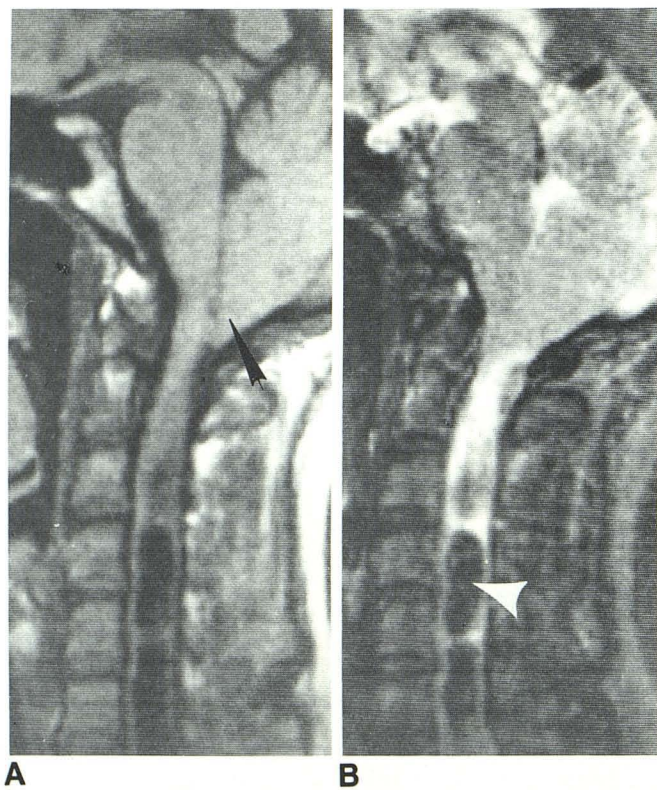


Fig. 7.—46-year-old woman with Chiari I malformation and syringomyelia. Note "beaded" shape of syrinx cavity. A, SE 500/40. "Pointed" tonsil below foramen magnum (arrow). B, SE 3000/120. "Beaded" shape is more noticeable on this T2-weighted image. Note CFVS in cavity (arrowhead). Increased intensity present at rostral end of syrinx may represent gliosis.

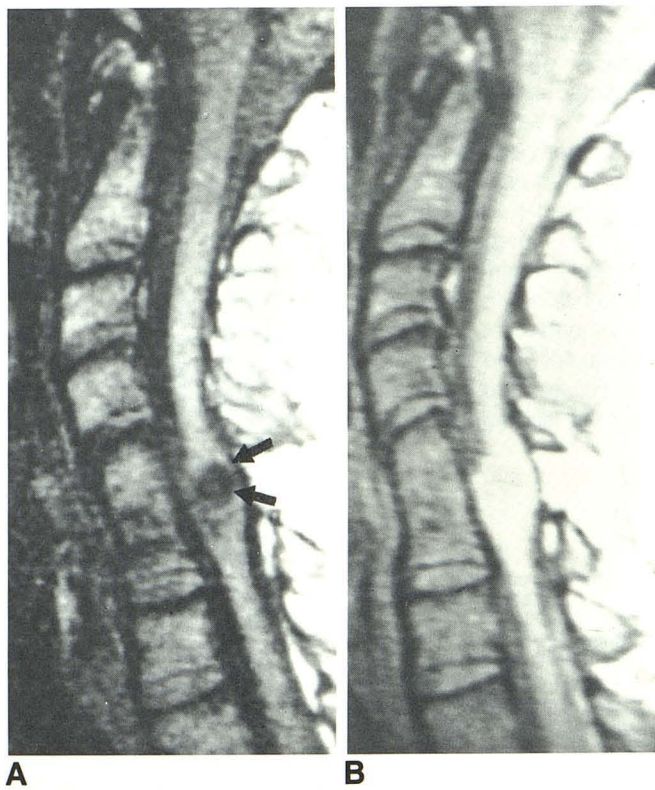


Fig. 8.—42-year-old man. Posttraumatic focal syrinx. Fusion at C5–C6. A, SE 600/30. Cyst enlarges cord (arrows). B, SE 2500/60. Diffuse increased intensity in syrinx and cord.

noid cisterns (Fig. 8). The CFVS was identified in the syrinx cavity in four of the 14 patients with adequate T2-weighted images (Fig. 9). Ten patients had no evidence of the CFVS. In one patient, multiple cysts were present in the thoracic

cord, causing marked cord enlargement (Fig. 9). Multiple drainage procedures over an 18-month period failed to halt the development of progressive cavitations and cord enlargement. The CFVS was initially seen only in a small area of the

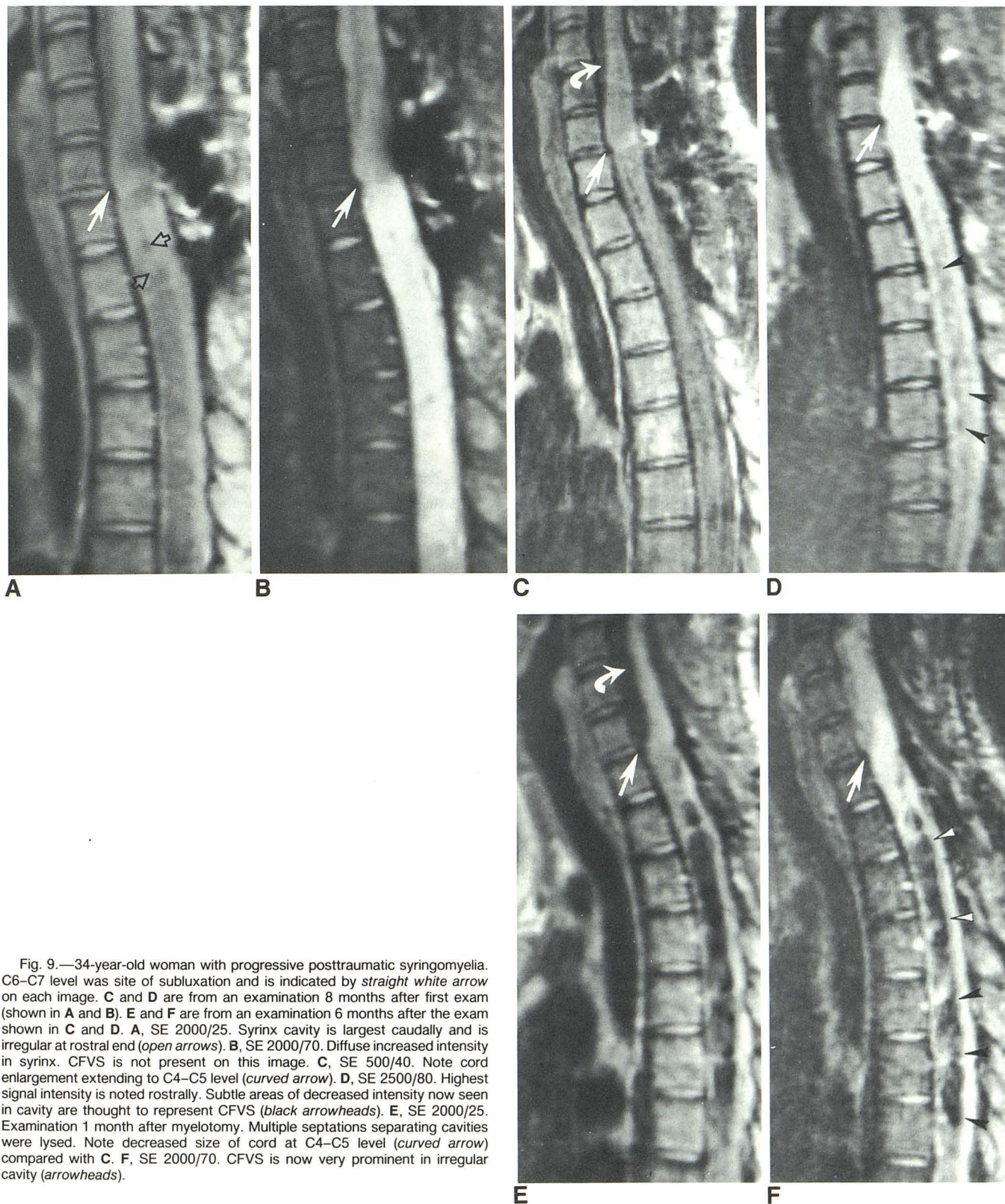


Fig. 9.—34-year-old woman with progressive posttraumatic syringomyelia. C6–C7 level was site of subluxation and is indicated by *straight white arrow* on each image. **C** and **D** are from an examination 8 months after first exam (shown in **A** and **B**). **E** and **F** are from an examination 6 months after the exam shown in **C** and **D**. **A**, SE 2000/25. Syrinx cavity is largest caudally and is irregular at rostral end (*open arrows*). **B**, SE 2000/70. Diffuse increased intensity in syrinx. CFVS is not present on this image. **C**, SE 500/40. Note cord enlargement extending to C4–C5 level (*curved arrow*). **D**, SE 2500/80. Highest signal intensity is noted rostrally. Subtle areas of decreased intensity now seen in cavity are thought to represent CFVS (*black arrowheads*). **E**, SE 2000/25. Examination 1 month after myelotomy. Multiple septations separating cavities were lysed. Note decreased size of cord at C4–C5 level (*curved arrow*) compared with **C**. **F**, SE 2000/70. CFVS is now very prominent in irregular cavity (*arrowheads*).

syrinx but subsequently developed to a much greater degree in an area that had previously appeared bright on a T2-weighted image. Finally, the patient underwent an extensive myelotomy and syrinx shunt revision, which disclosed multiple discontinuous cysts of various sizes and multiple septations. Repeat MR examination revealed that the multiloculated, discontinuous syrinx had been converted to a tubular syrinx with a single dominant cavity. The syrinx had a beaded appearance and the CFVS was present throughout most of the length of the syrinx. The length of the syrinx was reduced by two vertebral segments and the diameter was reduced by 1–2 mm. The patient reported symptomatic improvement.

The cerebellar tonsils ranged from 4 mm below to 10 mm above the foramen magnum, with an average position of 2 mm above. The two patients with mild tonsillar ectopia had a convincing history of trauma. The cerebellar tonsils appeared normally shaped in all cases.

Syringomyelia Associated with Tumors

Nine of the 58 patients (16%) had syrinx cavities associated with tumors. This group consisted of five men and four women, ranging in age from 13 to 64 years, with an average age of 33 years. Four patients were examined before surgical intervention, the other six were examined postoperatively. All cases have been pathologically proven.

Four patients had astrocytomas (three cervical, one thoracic) (Figs. 10 and 11) while four patients had ependymomas (three cervicothoracic, one in the fourth ventricle) (Fig. 12). One patient had a meningioma at the T4 level that had been resected. The length of the syrinx cavities ranged from one vertebral segment to total spinal cord involvement. The average length was five to six segments. The location and length of the cavities are depicted in Figure 4. The total spinal cord syrinx was found in the patient with a meningioma at the T4 level. The shortest cavity was found in a patient with an astrocytoma. The patient with the fourth ventricular ependymoma had a syrinx cavity limited to the cervical spinal cord. The diameter of the syrinx cavities varied from 2 to 12 mm with an average of 7.3 mm. Intratumoral cystic areas, separate from the syrinx cavities, were seen in two patients (Fig. 10). All patients had T2-weighted scans that permitted evaluation of the CFVS. The CFVS was present in the syrinx cavities in two of nine patients. The CFVS was not seen in areas known to represent intratumoral cysts. All patients had variable areas of increased intensity in the spinal cord. These areas correlated with locations of the tumor tissue in the eight patients with intramedullary tumors, but could not be differentiated from adjacent edema, gliosis, or demyelination. All patients with intramedullary tumors had either focal (Figs. 10 and 12) or diffuse (Fig. 11) spinal cord enlargement. The patient with the meningioma also had areas of increased intensity at the site of surgery, but these were interpreted by us as representative of gliosis.

The location of the cerebellar tonsils could be determined in six patients. Tonsillar position ranged from 4 mm above the foramen magnum to 18 mm below, averaging 5 mm below. Three patients had significant tonsillar herniation (7 mm, 10 mm, 18 mm herniation) (Fig. 10). The tonsils appeared

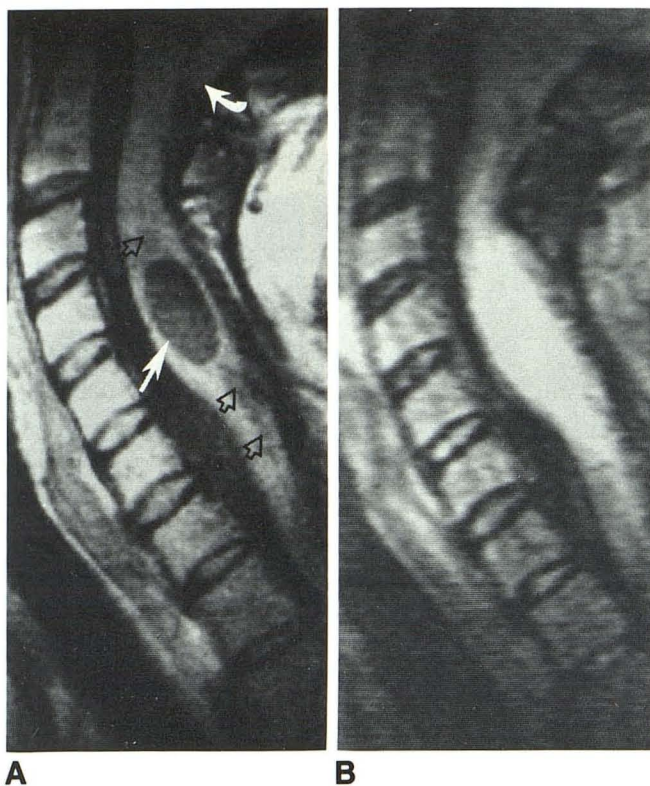


Fig. 10.—46-year-old woman with astrocytoma of cervical spinal cord. Laminectomies have enlarged spinal canal. A, SE 500/40. Focal ovate cyst enlarges cord (straight white arrow). Small spindle-shaped cavities above and below cyst (open arrows). Note tonsillar ectopia of 10 mm below foramen magnum (curved arrow). B, SE 2400/80. Diffuse increased intensity in cyst and in cavities above and below cyst. There is no evidence of CFVS.

normal in one patient with an ependymoma and in the patient with a meningioma. In four patients (including one with normal tonsillar position), the tonsils appeared pointed or compressed.

Idiopathic Syringomyelia

This group contained nine patients, four women and five men, ranging in age from 8 to 60 years; average age, 39 years.

Two of these patients (ages 8 and 46) had lumbar lipomeningoceles with spinal cord tethering. The central canal of the spinal cord was enlarged to 2 mm in both patients. There was no evidence of the CFVS in the hydromyelic cavities. Evaluation was limited to the lumbar area in the 46-year-old patient. In the younger patient there was no evidence of cervical or upper thoracic syringomyelia. The location and length of the cavities are shown in Figure 5. The cerebellar tonsils were at the level of the foramen magnum.

Six patients had syringomyelic cavities that resembled the cavities of the communicating syringomyelic group except that there was no evidence of craniocervical anomaly or hindbrain deformity. The average diameter of the cavities was 5.7 mm but ranged from 2 to 9 mm. Three patients had areas

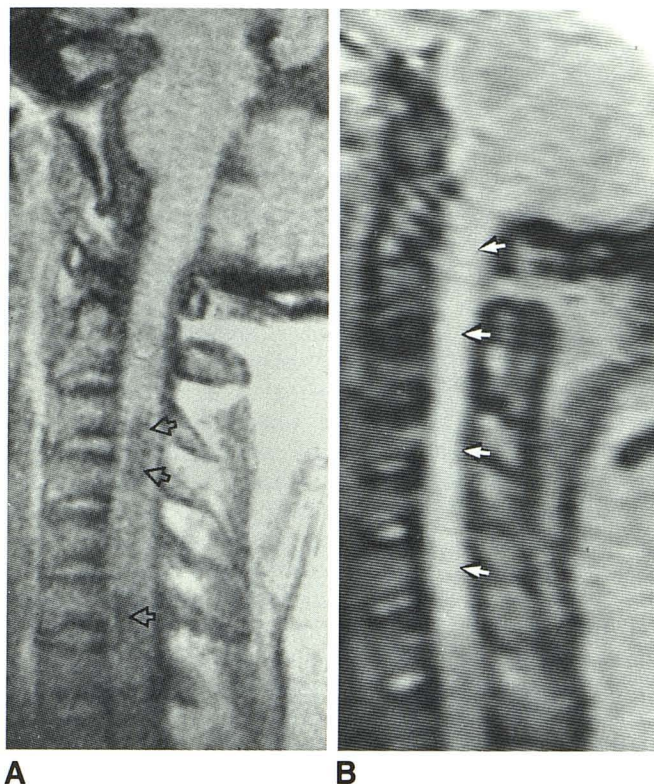


Fig. 11.—46-year-old man with diffuse cervical spinal cord astrocytoma. A, SE 800/30. Irregular cysts in diffusely enlarged cord (arrows). B, SE 2000/80. Diffuse increased intensity (arrows) represents tumor (pathologically proven at autopsy).

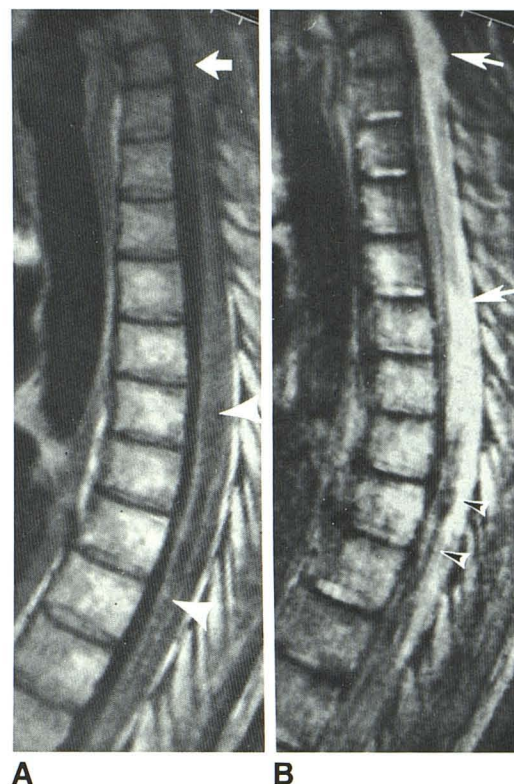


Fig. 12.—44-year-old man with recurrent ependymoma. A, SE 800/30. Syrinx cavity (arrowheads) in spinal cord below mass (arrow). Radiation changes noted in vertebral bodies. B, SE 2000/80. Increased intensity in tumor and spinal cord (arrows). CFVS is present in caudal aspect of syrinx (arrowheads).

of increased intensity in the spinal cord adjacent to the syrinx cavity on T2-weighted images. At surgery, these three patients had no evidence of spinal cord neoplasm. A biopsy in one case revealed gliosis. In four of six patients with sufficiently T2-weighted images, the CFVS was present in the syrinx cavity, extending most of the length of the cavity. The cerebellar tonsils and cisterna magna appeared normal in the seven patients whose cervical-cranial junction was evaluated, including one patient with a lumbar lipomeningocele.

Review of the Pathogenesis of Syringomyelia

Syringomyelia has many causes, just as cystic spaces in the brain may be of diverse origins. The shape and structure of the spinal cord and spinal canal have a strong influence on the appearance of the spinal cord cystic spaces, which makes the cavities and the clinical signs similar, regardless of the etiology.

Williams [12], Barnett [13], and others [14, 5] have adopted a classification system based on the way the syrinx communicates with the central canal. Thus, in "communicating" syringomyelia, the cavity contains fluid indistinguishable from CSF. This fluid is transmitted to the syrinx cavity via communication of the central canal with the fourth ventricle (Fig. 13). The cavitation in these cases should be centrally located.

This type is associated with the Chiari malformations. Gardner [6, 15] states that continuing communication between the fourth ventricle and the central canal is the result of a failure of the foramina of the fourth ventricle to open at the 29th week of fetal life. He describes a "water hammer effect" caused by CSF pulsations that is transmitted to the central canal. This causes the central canal to dilate, and, if the ependymal lining ruptures, causes cyst extension within the substance of the spinal cord (Fig. 13B). This theory was modified by Williams [16] to favor intracranial and spinal, venous, and CSF pressure differentials (Fig. 13C). Coughing and other maneuvers produce increased intrathoracic and intraabdominal pressure, which result in spinal epidural venous distention. Venous distention in the confined space of the spinal canal is accompanied by rapid displacement of spinal fluid into the head. In a patient with the Chiari I malformation or other obstruction, the initial surge forces CSF into the intracranial space but does not drain out immediately due to a ball-valve effect. Thus, there is craniospinal pressure dissociation. The higher intracranial pressure forces fluid into the central canal. A similar phenomenon is found in the spine in conditions that produce partial blockage [17]. Williams also theorizes that fluid shifts within the syrinx cavity lead to extension of cavities (Fig. 13C). Pulsation in the subarachnoid space may be transmitted to the fluid in the syrinx by gener-

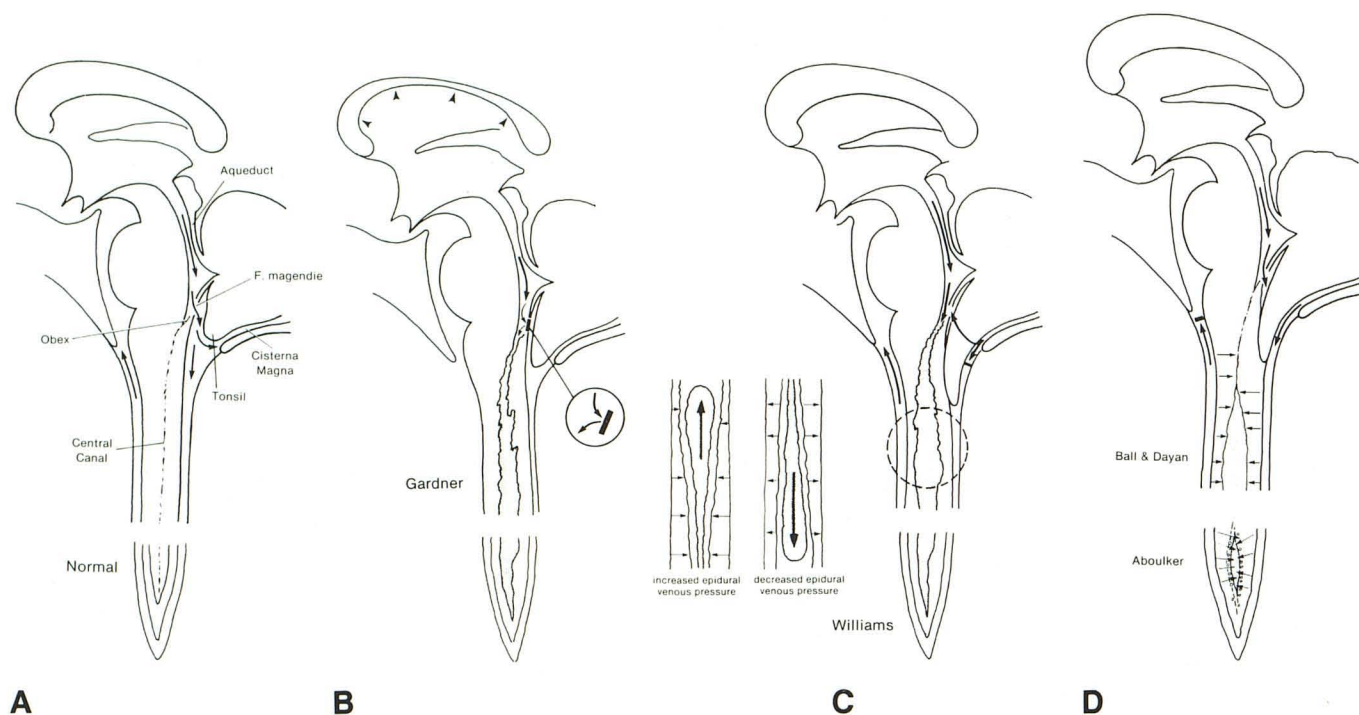


Fig. 13.—Diagrammatic representations of pathophysiological theories in syringomyelia. Refer to text for full explanation. **A**, Normal representation of CSF flow (arrows). Note incomplete central canal of spinal cord. **B**, Gardner's theory [6, 15] emphasizing imperforate foramen of Magendie (blocked arrow, inset). Hydrocephalus (arrowheads). **C**, Williams' theories [12, 16, 17] empha-

sizing "ball-valve" effect of foramen magnum obstruction. Movement of intracranial CSF into spinal canal is impeded (blocked arrow) and redirected into central canal. CSF movements in syrinx cavities depicted (inset). **D**, Theories of Ball and Dayan [20] and of Aboulker [21]. CSF movement from spinal canal into cranial space is impeded (blocked arrow). CSF passes into cord.

ating waves in the walls. These pulsations are thought to be caused by engorgement of the epidural venous plexus and are most marked in coughing and other Valsalva-like maneuvers [17–19]. As the veins fill, the increased pressure causes the fluid in the syrinx to be displaced. When the veins empty, the pressure is decreased and the displaced fluid returns to its original position. The gradual effect of these fluid shifts is to cause the cavity to extend into the part of the cord offering the least resistance.

In "noncommunicating" syringomyelia there is thought to be no direct communication with the subarachnoid space. The cavitations should be eccentric although they may appear centrally located on gross examination. Noncommunicating syringomyelia is said to be associated with trauma, tumor, or arachnoiditis.

These theories have helped the development of surgical procedures designed to correct the hypothesized etiologic abnormalities, but they are not universally accepted and there is conflicting evidence about the importance of the communication of the syrinx with the central canal [17, 20, 21]. Persistence of the syrinx in cases where the proposed communication via the calamus scriptorius [22] (at the obex) has been occluded are well known [20]. In addition, fluid within the syrinx in cases of trauma or arachnoiditis is identical to CSF in many instances.

Other theories have attempted to explain the origin of CSF in the cavity of a syrinx. Fluid may be secreted directly into

the syrinx by glial cells or ependyma lining the cavity [23].

Aboulker [21] and Aubin et al. [24] believe that obstruction at the foramen magnum causes increased spinal CSF pressure by inhibiting upward movement of CSF to sites of absorption (Fig. 13D). This is in contradistinction to Williams, who believes that foramen magnum obstruction prevents the downward passage of CSF. Aboulker theorizes that increased pressure drives CSF through the spinal parenchyma or via a pathway along the posterior roots into the spinal cord, where chronic edema gradually undergoes cavitation. The same basic mechanism is invoked by Ball and Dayan [20] except that they propose that the CSF passes into the spinal cord along perivascular (Virchow-Robin) spaces (Fig. 13D). These latter two theories have been invoked to explain the mechanism of metrizamide passage into noncommunicating syrinx cavities [25]. Hemorrhage into the syrinx (Gowers' syringal hemorrhage) is a rare cause of acute syrinx extension [13, 26].

Discussion

We noted many similarities in the appearance of the syrinx cavities despite the different origins (Table 1). Most cases involved the cervicothoracic junction (Fig. 1). Some patients with eccentric cord cavities were seen in every category, thereby eliminating this observation as a means of differen-

tiating "true" syringomyelia from "true" hydromyelia. Areas of cord enlargement or of cord atrophy were also noted in some patients in each category.

MR Intensity Differences in Syringomyelia

One of our most important observations in this series was the range of MR intensities that could be seen in the syrinx and the surrounding spinal cord. We noted areas of increased signal intensity on T2-weighted images in the spinal cord surrounding the syrinx cavities in 13 of 40 patients (33%) without tumors (nine patients did not have T2-weighted examinations) (Figs. 6, 7, 9). Gebarski et al. [27] noted similar areas on MR examinations in traumatic syringomyelia and hypothesized that these areas represented gliosis and/or edema. In two of our cases biopsies of the abnormal areas showed gliosis (Fig. 6). Gliosis is regarded as a reaction on the part of astrocytes to adjacent tissue damage and is composed of both hypertrophic and hyperplastic changes. Gliosis is commonly associated with syringomyelia [1, 2, 28, 29] and therefore its appearance on MR images is not surprising. Gliosis is proportional not only to the age of the lesion but to the severity of the forces acting upon the walls [29]. Thus, gliosis is found in a circumferential orientation to withstand a distending force and at the top of the cavity to withstand the upward pulsations of the syrinx fluid [8]. Circumferential gliotic bands produce the frequently seen "beaded" syrinx [1, 17, 28] (Fig. 7). Gliosis at the leading edge of the cavitation is also likely to occur because the leading edge of the cavity dissects along longitudinal tissue planes, separating the tissues from their intimate blood supply [28]. Greenfield [1] noted that where there is a recent extension the wall is irregular and consists of degenerated neuroglial and neural elements. In one patient with a traumatic syrinx (Fig. 9), the cavity was noted to extend in a rostral direction into an area that had previously been identified as having increased intensity on T2-weighted images. The surgeon subsequently reported his observation of gliosis and multiple small septated cavities in this area. In this same patient, the most recent rostral extension of the cavity was associated with an area of adjacent tissue of prolonged T2, but this area returned to normal after an extensive myelotomy and shunt revision. The return of an area of increased intensity to normal is most compatible with resolution of interstitial edema after successful cyst drainage [30]. Areas of prolonged T2 may also represent microcystic changes and demyelination, as Cohen et al. [31] have shown experimentally.

Prominent loss of signal intensity was seen in the syrinx cavity in many instances (Figs. 6, 7, 9, 12). We believe this represents pulsatile fluid shifts within the syrinx cavity. The MR appearance of CSF motion in the brain [10, 32-34] and in the spine [35-37] has been described. CSF motion appears as an area of decreased signal intensity compared with the CSF in the lateral ventricles or other CSF spaces not subject to marked pulsations. The loss of signal due to motion within CSF spaces such as the aqueduct of Sylvius has been referred to as the CSF flow-void sign (CFVS) [10, 32]. The signal loss represented by the CFVS is probably caused by a

combination of phase shift and time-of-flight effects [38, 39]. We hypothesize that the CFVS in the syrinx is caused by the fluid shifts that have been proposed by Williams [40].

It is important to note that although the syrinx CFVS was more frequently seen in the communicating syringomyelia group (81%), it was also present in some cavities of other types (Table 1). Although the CFVS can be seen on T1-weighted images, it is best seen on T2-weighted images. We found that the syrinx CFVS often prevented accurate assessment of the "true" intensity of the fluid in the syrinx cavity; that is, we were unable to determine differences in protein content in the syrinx fluid because of the CFVS [41]. The largest syrinx cavities were most likely to have the CFVS. The CFVS was seen in only one of four patients with cavities that were 2 or 3 mm in diameter. It was not present in tumor cysts (Figs. 10, 11) and was not seen in two ovoid traumatic cysts (Fig. 8). In the patient with an enlarging posttraumatic syrinx, the CFVS was initially present only in a small area (Fig. 9). Subsequent exams documented extension of the syrinx and increased visualization of the CFVS as multiple loculated cavities were converted into one dominant cavity. We theorized that the CFVS became more apparent as the separate syrinx cavities developed communications, thereby allowing greater mobility of fluid within the syrinx. We infer that the absence of the CFVS may indicate the presence of septations. These septations are probably fibrous or glial scars [42]. This is important information, since it may indicate the need for multiple syrinx drainage tubes or syringotomies to adequately shunt the syrinx. Intraoperative sonography is also useful in the detection of septations within syrinx cavities [27, 42].

Syringomyelia Associated with Tumor

Previous reports have noted that in cases of syrinx associated with spinal cord tumor, the tumor enlarged the spinal cord and often had an abnormal signal on T2-weighted images while the appearance of the cystic cavity was indistinguishable from other syringes [8]. Our series confirms this observation (Figs. 10, 11, 12). Spinal cord enlargement was present in eight patients (89%). It was not present in the patient with the posterior fossa ependymoma. In the presence of spinal cord cavitation cord enlargement alone is not specific for tumor (Table 1). Some reports have suggested that the presence of increased signal intensity around a syrinx was an indication of tumor [43]. As explained above, we have found that such areas are not infrequently seen in nonneoplastic conditions and that they represent gliosis in some cases (Figs. 6, 7, 9). Barnett [3] has stated that the syringes associated with tumors are most often lined by glial tissue and are secondary to CSF flow obstruction during periods of raised intraspinal pressure. He thus questions previous authors who have suggested that the cavitation occurs within the tumor mass.

Seven patients had intramedullary spinal tumors. In these cases the tumors could be detected by the presence of solid or mixed solid and cystic tissues at the site of cord enlargement (Fig. 11). The cystic areas within the tumors had higher intensity on T2-weighted sequences than the fluid in the syrinx

cavities. The CFVS was present in the associated syrinx cavities in two patients (Fig. 12) but was not present in the cystic portions of the tumors. However, we must caution that not all such cystic cavities are neoplastic. One patient had a traumatic focal syrinx (Fig. 8) that was very similar in appearance to a patient with a cystic astrocytoma of the cord (Fig. 10). Of course, the history of trauma and the related changes in the vertebral column allow differentiation on clinical grounds.

We cannot differentiate tumor in nonenlarged areas of the spinal cord from areas of gliosis, edema, myelomalacia, or demyelination (Fig. 12). The use of paramagnetic contrast agents such as Gd-DTPA has been advocated as a means of differentiating spinal cord neoplasms from edema and may prove useful in the differentiation of neoplasm from gliosis or myelomalacia [44].

The observation of the typical findings of the Chiari I malformation makes the consideration of tumor less likely, especially if a focal solid mass is not present. One such patient in our series was thought to have a tumor clinically and the initial pathologic diagnosis was Grade II fibrillary astrocytoma. The upper cervical spinal cord appeared hyperintense relative to all other tissues on a T2-weighted exam but the Chiari I malformation was also present (Fig. 6). At our urging, the tissue was reviewed at the Armed Forces Institute of Pathology and reclassified as gliosis without evidence of neoplasm. This case points out the importance of recognizing the typical features of the Chiari I malformation as well as recognizing that diagnostic difficulties are occasionally encountered on surgical biopsy specimens in distinguishing a poorly cellular diffuse fibrillary astrocytoma from reactive gliosis [45]. However, we must also recognize that tonsillar ectopia can coexist with spinal cord neoplasm. In fact, our series has a surprisingly high incidence of tonsillar ectopia in association with cervical spinal cord neoplasm and syringomyelia (Table 1). In these cases, the tumors were easily differentiated from the associated syringes on the basis of the anatomic characteristics.

Summary

We have shown that the appearance of syringomyelia is quite similar, regardless of the origin. The diagnosis of spinal cord neoplasm cannot be made on the basis of increased signal intensity alone.

Observation of the CFVS within the syrinx may have prognostic significance, since pulsatile fluid shifts appear to play a role in the extension of syrinx cavities. We cannot differentiate "communicating" from "noncommunicating" syringomyelia on the basis of the CFVS alone. However, the frequent observation of the CFVS in syrinx cavities supports Williams' theory that the cause of syrinx progression is related to fluid shifts in the cavity and is independent of the initial factors that lead to the development of the syrinx [17].

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