Liliequist Membrane: Three-dimensional Constructive Interference in Steady State MR Imaging

PURPOSE: To evaluate the Liliequist membrane in healthy volunteers by using three-dimensional (3D) Fourier transformation constructive interference in steady state (CISS) magnetic resonance (MR) imaging.

MATERIALS AND METHODS: In 31 volunteers, the authors performed 3D CISS MR imaging. They divided the membrane into three segments: the sellar, diencephalic, and mesencephalic segments. MR images were evaluated to identify the segments, superior and inferior attachments, lateral border, and thickness of the Liliequist membrane.

RESULTS: Three-dimensional CISS MR imaging depicted the sellar, diencephalic, and mesencephalic segments of the Liliequist membrane in the sagittal plane in 25 (81%), 16 (52%), and five (16%) of the 31 subjects, respectively. Transverse MR imaging depicted these segments in 24 (77%), 10 (32%), and two (6%) subjects, respectively, and coronal MR imaging depicted them in 24 (77%), 12 (39%), and two (6%) subjects, respectively. Clear attachment of the membrane to the dorsum sellae was observed in 22 (88%) of 25 subjects in whom the sellar segment was identified. Clear attachment to the mamillary body was identified in eight (50%) of 16 subjects in whom the diencephalic segment was identified. The Liliequist membrane was attached to the oculomotor nerve on seven (14%) of 50 sides of the lateral border and to the arachnoid membrane around the oculomotor nerve on 28 (56%) sides. In the sagittal plane, the thickness of the membrane was less than one-half the thickness of the third ventricle floor in 22 (88%) of 25 subjects.

CONCLUSION: The Liliequist membrane can be visualized by using 3D CISS MR sequences.

The Liliequist membrane was described by Key and Retzius (1) in 1875. In 1956, Liliequist (2,3) rediscovered the structure in his pneumoencephalographic studies of cadavers, which revealed this arachnoid membrane to be arising from the dorsum sellae to the anterior edge of the mamillary body. He also reported that during pneumoencephalography, the presence of this membrane initially caused the air to remain in the interpeduncular cistern before it gradually filled the chiasmatic cistern. Other authors subsequently described the Liliequist membrane on the basis of postmortem study results (4–7).

With the development of modern endoscopic techniques for neurovascular procedures, it has become possible to treat hydrocephalus endoscopically. Endoscopic third ventriculostomy, one of the most sophisticated of these techniques, is now widely performed because it is minimally invasive (8–12). With endoscopic third ventriculostomy, the floor of the third ventricle is fenestrated; then, the flow of cerebrospinal fluid (CSF) is diverted from the third ventricle to the subarachnoid space. Some authors have reported failures of this procedure (13,14). Buxton et al (13) proposed that the Liliequist membrane, which is not fenestrated during endoscopic third ventriculostomy, may have blocked the flow of CSF from the third ventricle.

The Liliequist membrane is also known to partially or completely obstruct CSF flow at the suprasellar cistern. It is also closely associated with the formation of the suprasellar...
Radiology

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(CISS) enables high-spatial-resolution

mensional (3D) Fourier transformation

structing membrane result in upward ex-

and increased pressure below the ob-

arachnoid cyst (15,16). Pulsations in CSF

ment in the literature on the lower at-

ach, however, there is disagree-

ment concerning the site of the superior

—namely, whether this at-

romamillary (4,7). This discordance may

be attributable to variation in the sites

of attachment. Similarly, conflicting de-

scriptions of the lateral border of the

Liliequist membrane have been reported:

have reported that the lateral edge of

the membrane attaches to the arach-

noidal sheath surrounding the oculomo-

tor nerve (4), whereas others have de-

scribed the lateral margins as attaching
to the pia mater covering the temporal un-
cus (5,7) or the tentorium (6).

In our review of the literature, the Lilie-

quist membrane has been identified in

many neuroanatomic studies, but in

most of these, the described findings

have been from cadaveric investigations,

and few studies have involved examina-

tion of the membrane in living individu-

als. As far as magnetic resonance (MR)
imaging studies are concerned, to our

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scribed the lateral margins as attaching
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It is well known that neuroanatomic

evaluations of the cisterns and surround-

ing structures are complicated. Three-di-

mensional (3D) Fourier transformation

constructive interference in steady state
(CISS) enables high-spatial-resolution

refocused gradient-echo MR imaging.

Three-dimensional CISS MR imaging de-
picts small structures surrounded by CSF

with high contrast and high spatial reso-

lution and is suitable for MR cisternogra-

phy. Cranial nerves III (18), IV (19), VI

(18,20), VII (21), VIII (21,22), and IX–XII

(23) have been successfully visualized on

MR images obtained by using 3D CISS

sequences. This sequence has also been

applied to virtual endoscopy of the CSF

space (24). The Liliequist membrane has

been described as a fine arachnoid mem-

brane in the subarachnoid space. There-

derefore, these reported successful visualiza-

tions of the cranial nerves led us to use 3D

CISS MR sequences to delineate the anat-

omic course of the Liliequist membrane.

The purpose of our study was to evaluate

the Liliequist membrane in healthy volun-
tees by using 3D CISS MR imaging.

MATERIALS AND METHODS

MR imaging examinations were performed

in 31 healthy volunteers (19 men aged

24–41 years [mean age, 30.2 years] and 12

women aged 24–53 years [mean age, 32.3

years]). The criterion for volunteer re-
cruitment was age between 20 and 60

years. All subjects were neurologically ex-

amined by one neurosurgeon (T.U.) and

received a diagnosis of neurologically

healthy. No subjects demonstrated neu-

rologic symptoms, which also were eval-

uated by T.U. The local ethics committee

at Kyoto University Graduate School of

Medicine approved the study, and all

participants provided written informed

consent before entering the study.

MR Imaging

All MR imaging examinations were per-

formed with a 1.5-T unit (Magnetom Sym-

phony; Siemens, Erlangen, Germany) by

using a regular head coil. A 3D CISS pulse

MR sequence was used with the following

parameters: 12.30/6.15 (repetition time

ms/echo time msec), 70° flip angle, 160 × 160-mm (read × phase encode) field

of view, 70.0-mm slab thickness, 256 ×

256 matrix, 52 3D partitions, one slab,

0.6 × 0.6-mm pixel size, 0.6-mm effective

section thickness, one signal acquired, and

imaging time of 8 minutes 10 seconds.

Image Analysis

Data obtained with 3D CISS MR se-

quences were reconstructed in sagittal,

transverse, and coronal planes with a sec-
tion thickness of 0.6 mm. Images were

analyzed with a multiplanar reconstruc-
tion program (Siemens), which enabled

us to compare the position of any point

selected in one plane with the position of

the same point in the other two perpen-

dicular planes simultaneously. Two expe-

rienced neuroradiologists (Y.F. with 6

years experience, Y.M. with 17 years ex-

perience) analyzed the images collabora-

tively. Each neuroradiologist made initial

evaluations independently, and any dis-

agreements regarding final conclusions

were resolved by consensus between the

two neuroradiologists.

Anatomic Course and Identification of the Liliequist Membrane

We identified the Liliequist membrane

by using the following criterion: a thin

(ie, ≤ 1 mm) structure behind the infun-
dibulum, below the floor of the third

ventricle, and in front of the basilar ar-
tery recognized on more than three con-

secutive image sections. Next, we divided

the membrane into three segments and

named them the sellar, diencephalic, and

mesencephalic segments (Fig 1). These

three segments corresponded to the mi-

croanatomy of the Liliequist membrane
described in a previous report (4). The

identification of the Liliequist membrane

was assessed by using a three-score scale: A

score of 2 meant a positive identi-

fication; a score of 1; a highly probable identification; and a score of 0, no identifi-

cation.

Attachments of the Liliequist mem-

brane to the dorsum sellae and the mami-

llary body were assessed in the sagittal

plane. When there was clear continua-

tion of the membrane from the dorsum

sealla or from the mamillary body, the

membrane was described as demonstrat-

ing clear attachment. When continuity

was ill defined, this was defined as ob-

scure attachment. No continuity was de-

fined as absent attachment.

We also assessed each side of the lateral

border of the Liliequist membrane in the

coronal and transverse planes. We de-

fined the structure to which the mem-

brane first attached laterally as the lateral

border. When the lateral border was not

identified, it was described as such.

Finally, we visually assessed the thick-

ness of the Liliequist membrane at its

thickest part in the sagittal plane and

compared it with the thickness of the

third ventricle floor, because this floor

can always be identified near the mem-

brane and the thickness of this floor

seems to differ infrequently among indi-

viduals. Membrane thickness was de-

scribed as follows: less than one-half the

thickness of the floor, less than the thick-
ness of the floor but greater than or equal to one-half the thickness of the floor, or greater than or equal to the thickness of the floor.

RESULTS

The three segments of the Liliequist membrane (ie, sellar, diencephalic, and mesencephalic segments) were analyzed in the 31 subjects by using CISS MR sequences (Fig 2). In the sagittal plane, the sellar, diencephalic, and mesencephalic segments were identified (score of 1 or 2) in 25 (81%), 16 (52%), and five (16%) of the 31 subjects, respectively (Table 1). In the transverse plane, these segments were identified in 24 (77%), 10 (32%), and two (6%) subjects, respectively (Table 1). In the coronal plane, the segments were identified in 24 (77%), 12 (39%), and two (6%) subjects, respectively (Table 1). When the Liliequist membrane was visualized, the sellar segment was always identified. In six individuals (19%), no segment of the membrane was visualized.

At MR examination in the 25 subjects in whom the sellar segment was identified in the sagittal plane, clear attachment to the dorsum sellae was observed in 22 subjects; obscure attachment, in two; and absent attachment, in one (Table 2). Among the 16 subjects with a recognizable diencephalic segment in the sagittal plane, clear attachment to the mamillary body was identified in eight subjects (Table 2), and in all eight of them, the diencephalic segment was attached to the front aspect of the mamillary body. Obscure and absent attachments to the mamillary body were seen in seven subjects and one subject, respectively (Table 2).

In 25 subjects, the Liliequist membrane could be identified in the coronal or transverse planes—that is, some segments of this membrane were recognizable (score of 1 or 2) in these planes. The right and left sides of the lateral border of the Liliequist membrane were assessed in these 25 subjects (50 sides) (Table 3). On three right sides and four left sides, the membrane directly attached to the oculomotor nerve (Fig 3, Table 3). On 15 right sides and 13 left sides, direct attachment was not confirmed; rather, the membrane appeared to be localized around the oculomotor nerve (Fig 4, Table 3). On seven right sides and eight left
sides, the lateral border of the Liliequist membrane was unidentifiable (Table 3).

As previously mentioned, the Liliequist membrane in 25 subjects was visualized in the sagittal plane—that is, some segments of this membrane were recognizable (score of 1 or 2) in this plane. In 22 of these 25 subjects, the thickness of the membrane in the sagittal plane was less than one-half the thickness of the third ventricle floor. In three subjects, the thickness of the membrane was less than that of the floor but either greater than or equal to one-half the floor’s thickness (Fig 5). No membranes had a thickness greater than or equal to the thickness of the third ventricular floor (Table 4).

**DISCUSSION**

With the development of microsurgery and the introduction of endoscopic techniques to intracranial surgery, the Liliequist membrane has come to be considered an important structure. However, to our knowledge, there have been no studies of the MR imaging assessment of the Liliequist membrane in healthy living individuals.

Of the three segments of the Liliequist membrane, the sellar segment was the most frequently identified at 3D CISS MR imaging. This segment was identified in 16 subjects and the mesencephalic segment in only five. Since the mesencephalic membrane is thinner than the diencephalic membrane and frequently incomplete and contains an opening through which the basilar artery ascends (4), it may be difficult to identify the mesencephalic segment on MR images. Zhang and An (6) reported that 43% of the 35 cadavers that they examined did not have identifiable diencephalic or mesencephalic components of the Liliequist membrane. Our study results partly support this finding: We identified the diencephalic and mesencephalic segments in at least five subjects (16%) at 3D CISS MR imaging. Both of these components were less frequently detected in the present study, probably because the mesencephalic membrane was thinner, incomplete, or fenestrated and was difficult to visualize with 3D CISS MR imaging. Likewise, regarding the segments that were not identified at MR imaging (score of 0), in some cases, the segment might have existed but could not be depicted for the same reason.

Disagreements regarding the superior attachment of the Liliequist membrane exist in the literature. Our data support the idea of a prelamellar attachment, although some exceptions might exist for subjects with unidentifiable (score of 0) diencephalic segments at MR imaging. Our study data reconfirmed that the inferior attachment of the membrane is the dorsum sellae.

The lateral margins of the Liliequist membrane were observed directly attaching to the oculomotor nerve on seven of the 50 sides identified with 3D CISS MR imaging. On another 28 sides, the lateral margins were close to the oculomotor nerve; these findings indicate that the arachnoid membrane around the oculomotor nerve connected with the Liliequist membrane. Matsumoto et al (4) reported that the lateral edges of the Liliequist membrane were attached to the arachnoid sheath surrounding the oculomotor nerve. Brasil and Schneider (5) documented that the lateral borders of the membrane were above the oculomotor nerve and attached laterally to the pia of the mesial surface of the temporal un-

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**TABLE 1**

Identification of Sellar, Diencephalic, and Mesencephalic Segments of Liliequist Membrane in 31 Subjects

<table>
<thead>
<tr>
<th>Identification Score*</th>
<th>Sagittal Plane</th>
<th>Transverse Plane</th>
<th>Coronal Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sellar</td>
<td>Diencephalic</td>
<td>Mesencephalic</td>
</tr>
<tr>
<td>2</td>
<td>22 (71)</td>
<td>10 (32)</td>
<td>2 (6)</td>
</tr>
<tr>
<td>1</td>
<td>3 (10)</td>
<td>6 (19)</td>
<td>3 (10)</td>
</tr>
<tr>
<td>0</td>
<td>6 (19)</td>
<td>15 (48)</td>
<td>26 (84)</td>
</tr>
</tbody>
</table>

Note.—Data are numbers of segments identified in the given planes. Numbers in parentheses are percentages.

* Score definitions: 2 = positive identification, 1 = highly probable identification, 0 = no identification.

**TABLE 2**

Attachment of Liliequist Membrane Segments to Dorsum Sellae and Mamillary Body

<table>
<thead>
<tr>
<th>Depiction of Attachment</th>
<th>Sellar Sellae Attachment</th>
<th>Mamillary Body Attachment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>22 (88)</td>
<td>8 (50)</td>
</tr>
<tr>
<td>Obscure</td>
<td>2 (8)</td>
<td>7 (44)</td>
</tr>
<tr>
<td>Absent</td>
<td>1 (4)</td>
<td>1 (6)</td>
</tr>
<tr>
<td>All</td>
<td>25</td>
<td>16</td>
</tr>
</tbody>
</table>

Note.—Data are numbers of sellar and diencephalic segments identified (score of 1 or 2) in the sagittal planes to be attached to the given structures. Numbers in parentheses are percentages.

**TABLE 3**

Attachment of Lateral Border of Liliequist Membrane to Oculomotor Nerve

<table>
<thead>
<tr>
<th>Type of Attachment</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly to oculomotor nerve</td>
<td>3 (12)</td>
<td>4 (16)</td>
</tr>
<tr>
<td>Around oculomotor nerve</td>
<td>15 (60)</td>
<td>13 (52)</td>
</tr>
<tr>
<td>Lateral border not identified</td>
<td>7 (28)</td>
<td>8 (32)</td>
</tr>
<tr>
<td>All</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Note.—Data are numbers of sides of the Liliequist membrane identified (score of 1 or 2) in the coronal or transverse planes. Numbers in parentheses are percentages.
Vinas and Panigrahi (7) reported that the lateral margins of the Liliequist membrane were attached to the pia on the mesial surface of the temporal uncus. Zhang and An (6) observed the Liliequist membrane extending laterally and continuing with the tentorium above and below the tentorial edge. They commented, however, that the arachnoid trabecular network has very wide connections with surrounding structures and that borders of the irregular network may vary widely among individuals.

Our results support the contention that the Liliequist membrane attaches to the oculomotor nerve or to the arachnoid membrane surrounding the nerve, but this membrane may well extend further laterally beyond the oculomotor nerve. We could not identify the lateral borders of 15 sides, probably because the cisternal anatomy is too complicated to visualize at MR imaging.

In the present study, 3D CISS MR sequences played an important role in the identification of the Liliequist membrane and its relationship with the oculomotor nerve. CSF artifacts existed to varying degrees but did not impede visualization of the Liliequist membrane in most subjects. Since the Liliequist membrane is a cisternal structure, the 3D CISS MR sequence was quite useful in this study.

The Liliequist membrane is the arachnoid membrane dividing the chiasmatic and interpeduncular cisterns. The predominant amount of CSF is known to flow through the ventral surface of the brain stem to the interpeduncular cistern. When complete, the Liliequist membrane may block CSF flow from the interpeduncular cistern. Without perforation of the Liliequist membrane, third ventriculostomy may fail and further interventions to perforate the membrane may be necessary (13). Before performing CSF diversion procedures such as endoscopic third ventriculostomy, determining whether the Liliequist membrane is complete may prove useful. Future pre- and postoperative studies may reveal the clinical usefulness of CISS MR imaging in endoscopic third ventriculostomy. Present study results show that the Liliequist membrane can be visualized in most healthy subjects by using 3D CISS MR sequences.

Acknowledgments: The authors are grateful for the help and technical assistance of Ari Kobayashi, RT, and Akira Hiraga, RT.

Table 4

<table>
<thead>
<tr>
<th>Thickness of the Floor</th>
<th>No. of Membranes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;½ Floor</td>
<td>22 (88)</td>
</tr>
<tr>
<td>≥½ Floor</td>
<td>3 (12)</td>
</tr>
<tr>
<td>All</td>
<td>25</td>
</tr>
</tbody>
</table>

Note.—The thickest segment of the membrane in the sagittal plane was compared with the thickness of the floor of the third ventricle. Numbers in parentheses are percentages.

* <½ Floor = less than one-half the thickness of the floor, ≥½ Floor = thickness less than the thickness of the floor but greater than or equal to one-half the thickness of the floor.
References

John D. Ward, MD
Clinician’s Commentary

Fushimi et al (1) have performed an elegant study of the anatomic variations of the membrane of Liliequist. They have rightfully noted the potential importance that this anatomic variation may have in the success or failure of endoscopic third ventriculostomy (ETV).

The overall success rate of ETV is around 75% (2–4). However, this leaves a population of patients in whom the procedure does not work. The obvious question is why? Several studies have tried to address this question (4–7).

In performing ETV, the intent is to perforate the floor of the third ventricle. When “failures” of ETV are analyzed, the emphasis is usually on whether there was a patent stoma of the third ventricle (7). In one study in which the potential failures of an ETV procedure were assessed, a 36% variation of the anatomy, with a thickened floor of the third ventricle being the most common, was reported (6). No mention was made of the anatomic variations of the membrane of Liliequist. Another study, focusing on imaging correlates of successful ETV, concentrated on ventricular size and a flow void in cine flow studies.

It is interesting that 75% of unsuccessful ETV procedures involve an absence of a flow void, but there is no mention of where the blockage existed. The presumption is that it was at the level of the floor of the third ventricle (5). In another study, repeat endoscopy was performed in the cases of failed ETV; a patent third ventricle perforation was present in seven of 12 patients (8). Whether the membrane of Liliequist had a role in these failed procedures is unknown. However, as the results of the present study by Fushimi et al (1) indicate, failure to assess the anatomy of the membrane of Liliequist may be an important factor that needs to be addressed in the future.

References

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