Morphological Analysis of the Sylvian Fissure Stem to Guide a Safe Trans-sylvian Fissure Approach

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Abstract

The sylvian fissure stem and its deep cisternal part (SDCP) consist mainly of the orbital gyrus (OG) and anterior medial portion of the temporal lobe. SDCP’s adhesion has been found to make a trans-sylvian approach difficult due to the various patterns of adhesion. Thus, in this study, we aim to clarify the morphological features of the SDCP, and to guide a safe trans-sylvian approach. We retrospectively classified the morphology of the SDCP in 81 patients into 3 types (tight, moderate, loose type) according to the degree of adhesion of the arachnoid membrane and analyzed the morphological features of the OG and the temporal lobe using intraoperative video images. In addition, we have retrospectively measured each width of the SDCP’s subarachnoid space at the three points (Point A, lateral superior portion; Point B, downward portion; Point C, medial inferior portion of SDCP) and analyzed their relationship to the degree of adhesion using the preoperative coronal three-dimensional computed tomography angiography (3D-CTA) images of 44 patients. As per the results, SDCP’s adhesions were determined to be significantly tighter in cases with large OG and young cases. The temporal lobe had four surfaces (posterior, middle, anterior, and medial) that adhered to the OG in various patterns. The tighter the adhesion between the OG and each of the three distal surfaces of the temporal lobe, the narrower the width of the subarachnoid space at each point (A, B, C). Understanding of the morphological features of the SDCP, and estimating its adhesion preoperatively are useful in developing a surgical strategy and obtaining correct intraoperative orientation in the trans-sylvian approach.

Keywords: orbital gyrus, planum polare of the temporal lobe, sylvian fissure stem, trans-sylvian approach

Introduction

In the trans-sylvian approach, complete dissection of the sylvian fissure is deemed crucial to obtain the wide operative field.1-6 There are two main factors that can impede a wide opening of the sylvian fissure: pattern of the sylvian veins7-22 and adhesion of arachnoid membrane of the sylvian fissure, especially the stem and its deep cisternal part (SDCP).8,22-24 The sylvian veins should be sufficiently peeled during the procedure; however, the SDCP may have tight adhesions that reduce the ability to widely open the sylvian fissure, making the operation difficult. However, few studies have conducted morphological analyses of adhesion of the sylvian fissure.8,22-24

In this study, we aim to clarify the morphological features of the SDCP using intraoperative video images and to investigate a method of estimating the degree of its adhesion using the preoperative computed tomography (CT), which would facilitate the good intraoperative orientation and the safe dissection of the SDCP in the trans-sylvian approach.

Anatomical explanation

It is important to understand the anatomy of the sylvian...
The sylvian fissure has been determined to have superficial and deep parts. The superficial part includes the stem located on the basal surface and the three rami (anterior horizontal, anterior ascending, and posterior rami) located on the lateral surface. The stem starts just lateral to the anterior perforated substance, between the lateral olfactory striate and the rhinal sulcus, and proceeds laterally and anteriorly toward the lateral surface of the hemisphere.

The posterior ramus proceeds posteriorly and superiorly between the frontal and parietal lobes and the temporal lobe. They then divide at the anterior sylvian point (ASP) just inferior to the pars triangularis of the inferior frontal gyrus (Fig. 1a). Classically, the deep part of the sylvian fissure is divided into the sphenoidal compartment and the operculoinsular compartment. The sphenoidal compartment arises in the region of the limen insula at the lateral margin of the anterior perforated substance. It is a narrow cleft along the proximal segment (M1) of the middle cerebral artery (MCA) between the frontal and temporal lobes that communicates medially with the carotid cistern. The operculoinsular compartment is located deep to the three superficial rami of the sylvian fissure on the lateral surface. However, as per Wen et al., the deep part of the sylvian fissure on the basal surface is not restricted to the sphenoidal compartment, but extends upward over the anterior surface of the insula. This transition region between the sphenoidal compartment and the operculoinsular compartment was named "anterior operculoinsular compartment" by Wen et al. Thus, the SDCP, as analyzed this time, are exactly the sphenoidal compartment and anterior operculoinsular compartment. As shown in Fig. 1a, this frontal lobe component (the operculum) mainly consists of the posterior and lateral orbital gyrus (OG), whereas the temporal lobe component consists of the planum polare (PP), which corresponds to the anterior portion of the upper medial surface of the temporal lobe and the parahippocampal gyrus. It is supposed that the large OG (as indicated by the green dotted line in Fig. 1a) or the large temporal lobe can form a tight and extensive adhesion of the SDCP.

### Materials and Methods

This retrospective study includes 81 patients (age range, 45-93 years; mean age, 69.6 years; 22 males, 59 females) that underwent the trans-sylvian approach for aneurysms (37 cases of ruptured aneurysm, 44 cases of unruptured aneurysm) at our institute from August 2011 to August 2019. (1) Morphological analysis of the SDCP was performed using intraoperative video images of 81 patients. (2) Measurement of the width of SDCP’s subarachnoid space and analysis of their relationship to the degree of adhesion were performed using the preoperative coronal three-dimensional computed tomography angiography (3D-CTA) images of 44 patients.

All procedures in this study were approved by the Institutional Review Board and Ethics committee of Graduate School of Biomedical and Health Sciences, Hiroshima University. Written informed consent was provided by all patients.

#### Method 1: Intraoperative video image analysis of the SDCP morphology

In principle, we performed the distal trans-sylvian approach in all cases. In all cases of subarachnoid hemorrhage, the ventricular drainage was placed before craniotomy and 10-15 mL of cerebrospinal fluid was drained. So, the preoperative and intraoperative condition seemed to have almost no effect for classification.

We then classified sylvian fissure morphology into three types according to the degree of SDCP’s adhesion through intraoperative video images of 81 patients, namely, tight, moderate, and loose. The tight type shows no subarachnoid space for closed micro-scissors between the OG and the temporal lobe with tight adhesion of the arachnoid membrane around the SDCP with retraction of the brain. The moderate type shows a sufficient subarachnoid space for closed micro-scissors between the OG and the temporal lobe by moderate retraction of the brain. The loose
Fig. 1b  Morphological features of the OG. The OGs were classified into three types based on the size. The yellow dashed line indicates a straight line drawn from the ASP to the sphenoid ridge at a point that turns almost in a straight line toward the anterior clinoid process. Green arrowheads indicate the posterior rim of the OG.

Type shows a sufficient subarachnoid space without retraction of the brain. Even in cases of subarachnoid hemorrhage, sufficient cleaning of the operative field with an irrigation system was able to make it possible to evaluate the degree of adhesion. Next, we investigated the morphological features of the OG and the temporal lobe in detail for each case and analyzed the part and degree of adhesions. We tentatively defined the OG as follows. A "large OG" has a posterior surface that protrudes lateral by 2 mm or more to a straight line from the ASP to the sphenoid ridge at a point that turns almost in a straight line toward the anterior clinoid process, a "medium OG" has a posterior surface that lies almost along the straight line, and a "small OG" has a posterior surface that lies medial by 2 mm or more to the straight line (Fig. 1b).

To evaluate the adhesion with OG, we divided the surface of temporal lobe into four parts (Fig. 1c, d), that is, A part (posterior surface), B part (middle surface), C part (anterior surface), and D part (medial surface). The posterior, middle, and anterior surfaces correspond to the PP, whereas the medial surface corresponds to the parahippocampal gyrus.

Statistical analysis
For statistical analysis of the correlation between the degree of sylvian fissure stem adhesion and the size of OG, categorical variables were compared using chi-square test. For statistical analysis of the correlation between the size of OG and age, continuous variables were compared by using ANOVA with Tukey's post hoc comparisons for multiple groups.

Method 2: Preoperative CT coronal image analysis of the SDCP morphology
We have retrospectively selected the preoperative coronal three-dimensional computed tomography angiography (3D-CTA) images of 44 unruptured cases out of the 81 cases because the morphology of the SDCP was not demonstrated accurately in the cases of subarachnoid hemorrhage. We used the workstation of GE Healthcare (Volume Viewer®) and selected a slice of coronal 3D-CTA images at the site corresponding to the limen insula on a slice of axial 3D-CTA images for each case. These images demonstrated the SDCP well and each width of subarachnoid space between the OG and the PP was measured at the
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The frontal lobe component of SDCP mainly consists of the posterior and lateral OG. The temporal lobe component of SDCP consists of the PP, which corresponds to the anterior portion of the upper medial surface of the temporal lobe, and the parahippocampal gyrus. The temporal lobe is known to have four surfaces that can adhere to the OG. Part A (white area) indicates the posterior surface of the temporal lobe (PP). Part B (yellow area) indicates the middle surface of the temporal lobe (PP). Part C (brown area) indicates the anterior surface of the temporal lobe (PP). Part D (pink area) indicates the medial surface of the temporal lobe (parahippocampal gyrus). It is supposed that the large OG (as indicated by the green dotted) or the large temporal lobe can form a tight and extensive adhesion of the SDCP.

Fig. 1c  Morphological features of the temporal lobe.

PP, planum polare of the temporal lobe; SDCP, stem and its deep cisternal part

Results

Results 1: Intraoperative video image analysis of the SDCP morphology

As shown in Table 1a, we classified the 81 patients into three types (tight type, moderate type, loose type) based on the degree of SDCP’s adhesion. The tight type was observed in 33.3% (n = 27) of the patients, with the large OG observed most commonly. The moderate type was observed in 30.9% (n = 25) of the patients, with the medium OG observed most commonly. The loose type was observed in 35.8% (n = 29) of the patients, with the small OG observed most commonly. There was a significant difference in the OG size among the three types (P < 0.05). The patients of tight type were significantly younger than the patients of other type (moderate, loose) (P < 0.05). The patients with large OG were significantly younger than the patients with other size (medium, small) OG (P < 0.05) (Table 1b). However, there were a few cases in which adhesions were tight even in medium OG and in cases which adhesions were moderate even in large OG. This can be attributed to the size of the temporal lobe (Table 1a).

Although it was difficult to objectively and accurately evaluate the size of temporal lobe from the intraoperative video images, we observed that the temporal lobe has four surfaces (posterior, middle, anterior, and medial), all of which could adhere to the OG to various degrees (Table 1c). The posterior, middle and anterior surfaces correspond to the PP. The medial surface corresponds to the parahippocampal gyrus (Fig. 1c, d). Thus, we were able to anatomically describe the adhesion status of the SDCP as adhesion between the OG and these four surfaces of the temporal lobe.
Fig. 1d Operative view of the SDCP.
As the dissection of the stem proceeds from the distal to the proximal portion, each surface of the temporal lobe appears. Part A (white dashed line) indicates the posterior surface of the temporal lobe (PP). Part B (yellow dashed line) indicates the middle surface of the temporal lobe (PP). Part C (brown dashed line) indicates the anterior surface of the temporal lobe (PP). Part D (pink dashed line) indicates the medial surface of the temporal lobe (parahippocampal gyrus). The adhesion between the OG and the anterior surface of the temporal lobe was tight in this case (tight type). Green arrowheads show the posterior rim of the OG.

Fig. 2a demonstrated a case of tight type of sylvian fissure morphology. In this case, the OG was slightly large and the adhesion between the OG and all four surfaces of the temporal lobe was very tight. Fig. 2b demonstrated a case of moderate type. In this case, the OG was medium size and the adhesion between the OG and the three distal (posterior, middle, and anterior) surfaces of the temporal lobe was moderate. The adhesion between the OG and the medial surface (parahippocampal gyrus) was loose. Fig. 2c demonstrated a case of loose type. In this case, the OG was small size, and the adhesion between the OG and distal three surfaces of the temporal lobe (PP) was loose. Only the adhesion between the OG and the medial surface was moderate. In addition, from the anatomical analysis of these intraoperative video images, it was demonstrated that continuous exposure from the internal carotid artery (ICA) to the M1 proximal segment was achieved by separating the tissue between the OG and at least the two proximal (anterior and medial) surfaces of the temporal lobe. Separating the tissue between the OG and at least the two distal (posterior and middle) surfaces of the temporal lobe exposed around the MCA bifurcation (Fig. 2a-c).

Results 2: Preoperative CT coronal image analysis of the SDCP morphology
The correlation between the degree of SDCP’s adhesions and the width of subarachnoid space of the SDCP on the coronal 3D-CTA images on the limen insula was demonstrated in Table 2. In cases with loose adhesion between the OG and the posterior surface of the PP, the subarachnoid space of Point A can be noted to be significantly wider than the cases with its tight or moderate adhesion (P < 0.05). In cases with loose adhesion between the OG and the middle surface of the PP, the subarachnoid space of Point B was significantly wider than the cases with its tight or moderate adhesion (P < 0.05). With regard to adhesion between the OG and the anterior surface of the PP, there was a significant difference in the subarachnoid space of Point C among the three groups (tight, moderate, and loose) (P < 0.05) (Table 2, Fig. 1e). Although it was difficult to accurately distinguish between tight and moderate adhesions, the tighter of adhesion between the OG and
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Fig. 1e (A-D). Estimation of the degree of SDCP’s adhesion using a slice of coronal 3D-CTA images preoperatively. (A) Point A which is the lateral superior subarachnoid space of the SDCP corresponds to the subarachnoid space between the OG and the posterior surface of the temporal lobe (PP). Point B which is the downward subarachnoid space of the SDCP corresponds to the subarachnoid space between the OG and the middle surface of the temporal lobe (PP). Point C which is the medial inferior subarachnoid space of the SDCP corresponds to the subarachnoid space between the OG and the anterior surface of the temporal lobe (PP). (B) The slice of coronal 3D-CTA images of tight type (Fig. 2a: right side) with tight adhesion between the OG and the three distal surfaces (posterior, middle, and anterior surfaces) of the temporal lobe (PP). The width of subarachnoid space between the OG and the PP at all points (A, B and C) was narrow. (C) The slice of coronal 3D-CTA images of moderate type (Fig. 2b: right side) with moderate adhesion between the OG and the three distal surfaces (posterior, middle, and anterior surfaces) of the temporal lobe (PP). The adhesion between the OG and the medial surface was loose. The width of subarachnoid space between the OG and the temporal lobe at all points (A, B, and C) was noted to be not so wide. (D) The slice of coronal 3D-CTA images of loose type (Fig. 2c: left side) with loose adhesion between the OG and the three distal surfaces (posterior, middle, and anterior surfaces) of the temporal lobe (PP). The width of subarachnoid space between the OG and the temporal lobe at all points (A, B, and C) was wide.

Table 1 Summary of intraoperative video image analysis of the SDCP morphology and its adhesion

| Adhesion of the SDCP | Tight type | Moderate type | Loose type |
|----------------------|------------|---------------|------------|
| Total number         | 27 (33.3%) | 25 (30.9%)    | 29 (35.8%) |
| The size of OG       |            |               |            |
| Large                | n = 25     | n = 3         | n = 0      |
| Medium               | n = 2      | n = 17        | n = 15     |
| Small                | n = 0      | n = 5         | n = 14     |
| Mean age             | 64.3†      | 71.6          | 72.9       |

*P < 0.05 vs. moderate type, †P < 0.05 vs. loose type.

| Size of OG | Large: n = 28 (34.6%) | Medium: n = 34 (41.9%) | Small: n = 19 (23.5%) |
|------------|-----------------------|------------------------|-----------------------|
| Mean age   | 65.9†                 | 71.4                   | 73.9                  |

*P < 0.05 vs. Medium OG, †P < 0.05 vs. small OG.

| Adhesion surface with the OG | Tight | Moderate | Loose |
|------------------------------|-------|----------|-------|
| Posterior surface of the PP  | n = 20 (25%) | n = 23 (28%) | n = 38 (47%) |
| Middle surface of the PP     | n = 13 (16%) | n = 12 (15%) | n = 56 (69%) |
| Anterior surface of the PP   | n = 24 (30%) | n = 16 (20%) | n = 41 (50%) |
| Medial surface (parahippocampal gyrus) | n = 7 (9%) | n = 23 (28%) | n = 40 (49%) |

Unknown: n = 11 (14%)

n, number; OG, orbital gyrus; PP, planum polare; SDCP, stem and its deep cisternal part unknown, unable to evaluate the degree of adhesion through the intraoperative video images.
Fig. 2a  A case of tight type of sylvian fissure morphology (right side: unruptured aneurysm of ICA).

The OG was slightly large, and the adhesion between the OG and all four surfaces of the temporal lobe was tight. The dissection of the stem proceeded from the distal part to the proximal part in a step by step manner. Part A (white dashed line) indicates the posterior surface of the PP. Part B (yellow dashed line) indicates the middle surface of the PP. Part C (brown dashed line) indicates the anterior surface of the PP. Part D (pink dashed line) indicates the medial surface of the temporal lobe (parahippocampal gyrus). After the dissection between OG and Part D, the ICA to the M1 proximal segment was continuously exposed at last. The area within the green lines shows the posterior OG. The area within the light green lines shows the lateral OG. The area within the sky blue line shows the pars triangularis. Red circle shows the ASP. Green arrowheads show the posterior rim of the OG. ICA, internal carotid artery; P-com, posterior communicating artery.

Discussion

In the trans-sylvian approach, complete dissection of the SDCP as well as sufficient dissection of the sylvian veins has been identified to be necessary to obtain a wide operative field. Complete dissection of the SDCP has several advantages for a safe and certain trans-sylvian approach. First, having sufficient mobility of the frontal lobe can avoid excessive retraction and risk of brain contusion. Second, complete dissection of the SDCP can also provide sufficient mobility to the temporal lobe. Temporal lobe mobility is very important in terms of obtaining a lateral operative view to confirm the perforators behind the aneurysm, especially in cases of an aneurysm on the posterior wall of the ICA or a large aneurysm. Furthermore, it is important to understand the morphological features of the SDCP for a safe and certain trans-sylvian approach.

Yasargil et al. have categorized the diversity of the SDCP into four types according to the relationship between the lateral OG and the superior temporal gyrus: (1) Type A has loose adhesion between the lateral OG and the temporal lobe, type B has tight adhesion, frontal type has the lateral OK herniated into the temporal lobe, and temporal type has the proximal part of the superior temporal lobe herniated into the lateral OG. However, as demonstrated from the results of previous reports, as well as in this study, the SDCP is composed mainly of the lateral and posterior OG and the temporal lobe (PP and parahippocampal gyrus). Therefore, the degree of SDCP's adhesion is dependent on the size of the lateral and posterior OG and the temporal lobe (PP and parahippocampal gyrus). Further-
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Fig. 2b  A case of moderate type (right side: unruptured aneurysm of ICA).

The OG was medium size, and the adhesion between the OG and the temporal lobe seemed to be tight. However, the subarachnoid space between the OG and the temporal lobe appeared with moderate retraction of the brain. The adhesion between the OG and the three distal surfaces (posterior, middle, and anterior) of the temporal lobe (PP) was moderate, and the adhesion between the OG and the medial surface of the temporal lobe (parahippocampal gyrus) was loose. The procedure of dissecting the SDCP was not so difficult.

SDCP, stem and its deep cisternal part

more, as per our investigation, the patterns of the degree of SDCP's adhesion can be anatomically described as a pattern of adhesions between the OG and the four surfaces of the temporal lobe. Thus, dissection of the SDCP is most difficult in cases with tight adhesion between the OG and all four surfaces of the temporal lobe (Fig. 2a). On the other hand, it is most easy to dissect the SDCP in patients with loose adhesion of them. In such cases, most of the SDCP is already automatically opened just by dissecting the sylvian veins (Fig. 2c).

Our investigation also revealed the anatomical relationship between the SDCP and the course of ICA and MCA. Dissection between the OG and at least the two proximal (anterior and medial) surfaces of the temporal lobe is required to expose the ICA to the M1 proximal segment. On the other hand, in order to expose the MCA bifurcation, it is necessary to dissect between the OG and at least the two distal (posterior and middle) surfaces of the temporal lobe. The additional dissection between the OG and the anterior surface of the temporal lobe is dependent on the course and the length of the M1. These findings guide a good intraoperative orientation in the trans-sylvian approach for aneurysms.

From these anatomical points of view, the important points of procedure to open the sylvian fissure widely in case of tight type are as follows:

1) The dissection should be started from the distal part of the ASP, and the dissection of the SDCP should be patiently proceeded step by step from the distal to the proximal part. The key step in this process is the sufficient dissection between the OG and the posterior surface of the temporal lobe in advance (Fig. 3), because the dissection of the distal part of the SDCP facilitates and ensures the dissection of tight adhesion of the proximal part. 3,35 By dissecting the distal part of the SDCP in advance, the surgeon can properly dissect from the deep cistern of the distal part with counter pressure by using a spatula or a suction tube and can easily use a micro scissor like a paper knife. Of course, in some cases, it is safe to expose the proximal portion of the ICA before the complete dissection of the SDCP. But even in such cases, the dissection should be restarted from the distal part of the SDCP after exposing the ICA via the subfrontal space.

2) For a ruptured MCA bifurcation aneurysm, the sur-
A case of loose type (left side: unruptured aneurysm of ICA). The OG was small size, and the adhesion between the OG and the distal three surfaces of the temporal lobe (PP) was loose. Only the adhesion between the OG and the medial surface was moderate. The distal portion of the SDCP was already automatically opened just by dissecting the sylvian veins. Complete dissection of the SDCP was achieved easily by only additional dissection between the OG and the medial surface of the temporal lobe.

Table 2  Correlation between the width of subarachnoid space on the coronal 3D-CTA images and the degree of SDCP’s adhesion

| Adhesion between the OG and the posterior surface of PP | Tight (n = 14) | Moderate (n = 15) | Loose (n = 18) |
|-------------------------------------------------------|----------------|------------------|---------------|
| Point A                                               | 1.7 ± 0.8 mm   | 2.6 ± 1.4 mm     | 4.7 ± 2.7 mm*|
| Adhesion between the OG and the middle surface of PP  | Tight (n = 9)  | Moderate (n = 10)| Loose (n = 28)|
| Point B                                               | 2.7 ± 1.3 mm   | 3.4 ± 0.7 mm     | 6.0 ± 1.4 mm*|
| Adhesion between the OG and the anterior surface of PP| Tight (n = 17) | Moderate (n = 7) | Loose (n = 23)|
| Point C                                               | 2.2 ± 1.0 mm   | 4.2 ± 1.4 mm*    | 6.7 ± 2.0 mm*|

* P < 0.05 vs. tight group. † P < 0.05 vs. moderate group.

n, number; 3D-CTA, three-dimensional computed tomography angiography; OG, orbital gyrus; PP, planum polare

gon should carefully dissect the deep cistern around the ASP, especially the adhesion between the OG and the two distal (posterior and middle) surfaces of the temporal lobe to prevent premature rupture. In many cases of an MCA bifurcation aneurysm, it is possible to expose the M1 safely from the distal side in the distal trans-sylvian approach.
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Fig. 3 Procedure of the complete dissection of the SDCP based on the sylvian fissure morphology. Especially in tight type cases, it is strongly recommended to start the dissection of the sylvian fissure from the distal part of the ASP and to release its deep cisternal part in advance (Step 1). Then, the dissection of the SDCP should be performed step by step from the distal to the proximal part (Steps 2→5). The key step to dissect the SDCP completely is the complete dissection between the OG and the posterior surface of the PP (Step 2). The insufficient dissection of them will make it difficult to release their proximal part with tight adhesion.

However, in cases with a large aneurysm or a short M1, it may be necessary to expose the proximal portion of the ICA in advance via the subfrontal space and to combine the dissection from the distal part and the proximal part of the SDCP in order to prevent premature rupture.

In this study, we have anatomically investigated the degree of SDCP’s adhesion and explained the procedure of the complete dissection of the SDCP based on the morphological features of the OG and the temporal lobe in the trans-sylvian approach. The degree of SDCP’s adhesion can be estimated using the coronal 3D-CTA images, and the difficulty of dissecting the sylvian fissure for each patient can be predicted with reference to this. Our findings provide a good guide when considering surgical procedures in the trans-sylvian approach, especially for inexperienced surgeons.

Conclusions

It is very crucial to understand the morphological features of the OG and the temporal lobe in order to obtain good intraoperative orientation and estimate the difficulty of dissecting the SDCP in the trans-sylvian approach. We were able to anatomically investigate and classify the degree of arachnoid adhesion of the SDCP in detail and present a safe and reliable method to open the SDCP widely according to the degree of its adhesion.

Conflicts of Interest Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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