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Repair of cerebrospinal fluid leak during posterior thoracolumbar surgery using paraspinal muscle flap combined with fat graft

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Objective: This study aimed to propose a novel surgical method *via* combination of fat graft and paraspinal muscle flap, in order to treat cerebrospinal fluid (CSF) leak during posterior thoracolumbar surgery. The clinical outcomes were also evaluated.

Methods: Data of a total of 71 patients who were diagnosed with intraoperative incidental durotomy and CSF leak after posterior thoracolumbar surgery in our hospital from January 2019 to January 2021 were retrospectively collected and analyzed. Among them, 34 and 37 patients were assigned into conventional suturing (CS) group and fat graft and paraspinal muscle flap (FPM) group, respectively. Patients' demographic and clinical data were compared between the two groups.

Results: The average drainage tube time in the FPM group was 3.89 ± 1.17 days, which was shorter than that in the CS group (5.12 ± 1.56 , $P < 0.001$). The drainage volume in the FPM group (281.08 ± 284.76 ml) was also smaller than that in the CS group (859.70 ± 553.11 ml, $P < 0.001$). Besides, 15 (44.11%) patients in the CS group complained of postural headache, which was more than that in the FPM group (7 patients, 18.91%). There was a statistically significant difference in postoperative visual analogue scale (VAS) score between the two groups ($P = 0.013$). Two patients underwent revision surgery resulting from incision nonunion and delayed meningeal cyst.

Conclusion: Fat graft combined with paraspinal muscle flap showed to be an effective method to repair CSF leak during posterior thoracolumbar surgery. The proposed method significantly reduced postoperative drainage tube time and postoperative drainage volume. It also decreased the incidence and the degree of postural headache. The proposed method showed satisfactory clinical outcomes, and it is worthy of promotion.

KEYWORDS

cerebrospinal fluid leakage, posterior approach, thoracolumbar surgery, muscle flap, fat graft

Background

Cerebrospinal fluid (CSF) leak after posterior thoracolumbar surgery is mainly caused by incidental durotomy intraoperatively, especially in the occasion of dural adhesion with surrounding tissue or abnormal ossification (1–4). As a common complication, the incidence rate of CSF leak ranges from 1% to 17.4% (4–7). The

effective treatment for CSF leak is dural suturing during surgery, however, anterior and a part of lateral dural rupture are difficult to suture. In addition, intraoperative suturing does not always fully prevent outflow of CSF (8, 9). Persistent postoperative CSF leak could lead to various low intracranial pressure symptoms, such as headache, dizziness, nausea, and vomiting (1, 4). Moreover, wound complications arose with the continuous outflow of CSF, such as nonunion, infection, and pseudomeningocele formation. Severe complications caused by CSF leak require revision surgery (3). CSF leak negatively affects clinical outcomes and patient satisfaction. Although different methods have been proposed to repair damaged dura mater and a variety of biological materials were used to block CSF leak, spinal surgeons still encounter numerous multifarious problems caused by CSF leak. The present study aimed to propose a combined method using fat graft and paraspinous muscle flap, in order to treat CSF leak after posterior thoracolumbar surgery and to evaluate the clinical outcomes. This novel method may assist clinicians to reduce the influence of CSF leak.

Study subjects and methods

Study subjects

Data of a total of 71 patients who were diagnosed with intraoperative incidental durotomy and CSF leak after posterior thoracolumbar surgery at the Third Hospital of Hebei Medical University (Shijiazhuang, China) from January 2019 to January 2021 were retrospectively collected and analyzed. The inclusion criteria were as follows: (1) patients who underwent thoracolumbar spine surgery; (2) patients who underwent posterior surgery only; (3) intraoperative CSF leak caused by incidental durotomy; (4) patients who aged >18 years old; (5) follow-up of at least 12-month. The exclusion criteria were as follows: (1) intraspinal tumors; (2) spinal infectious diseases; (3) a history of undergoing surgery involving spine; (4) intraoperative application of special biomaterials (e.g., an artificial dura mater); (5) incomplete clinical data.

There were 25 (35.21%) men and 46 (64.79%) women who were enrolled in the present study, and their average age was 51.64 ± 11.92 years old. The average follow-up time was 15.10 ± 4.15 months. The patients were operated by the same surgeon. Conventional suturing was used in 34 patients, and they were assigned into conventional suturing (CS) group. Fat graft and paraspinous muscle flap were used in other 37 patients to reduce CSF leak, and they were assigned into fat graft and paraspinous muscle flap (FPM) group. In addition, patients' basic characteristics, including body mass index (BMI), medical comorbidities (hypertension, diabetes, cardiac disease, cerebrovascular disease, and osteoporosis), smoking history, diagnostic method, surgical method, operation time, and

intraoperative blood loss were recorded for analysis. Location of dural tear was recorded by a chief surgeon as posterior, anterior, and lateral. Dural suturing was performed as far as possible and suture or non-suture repair was also recorded.

Surgical method

Posterior surgery was performed to treat thoracolumbar disease. When dural was torn incidentally, a piece of cotton was placed above the gap to shelter the CSF leak, followed by the remaining procedures of decompression and/or fusion. According to the location of gap, the dural tear was sutured as far as possible. Finally, incision was closed by a conventional method in the CS group or fat graft combined with paraspinous muscle flap method in the FPM group.

Conventional method

gelatin sponge was used to shelter the dural gap, the suturing was carried out layer by layer, and in particular, the layer of the thoracolumbar fascia should be tightly closed. Regarding the combination of fat graft with paraspinous muscle flap (Figure 1), autologous fat was removed from fat layer of sidewalls of incision that was used to shelter the dural gap (Figure 1A). Pedicle paraspinous muscle flap was made from both sidewalls of incision by tissue scissors. The location of pedicle paraspinous muscle flap was selected according to surrounding blood supply. Paraspinous muscle flap from a better blood supplied area was conducive to a longer survival. Two sides of paraspinous muscle flap were gathered and sutured together above the autologous fat for closing dead space of bilateral paraspinous muscles (Figure 1B). The suturing was performed in the same method as conventional method.

Drainage tube was placed routinely, and drainage pressure was normal and positive. Drainage tube time and total postoperative drainage volume were recorded in the two groups. Postoperative drainage was defined as the total volume from immediate post-operation to the time of tube removal.

Clinical evaluation

Questionnaire is the main method to evaluate the clinical outcomes, and clinical evaluation was performed preoperatively, postoperatively (3 days after surgery), and in the last follow-up visit. Japanese Orthopedic Association (JOA) score was used to evaluate the neurological function. JOA score for patients undergoing lumbar spine surgery ranged from 0 to 29. For patients undergoing thoracic surgery, JOA score was modified and the score ranged from 0 to 11 (10).

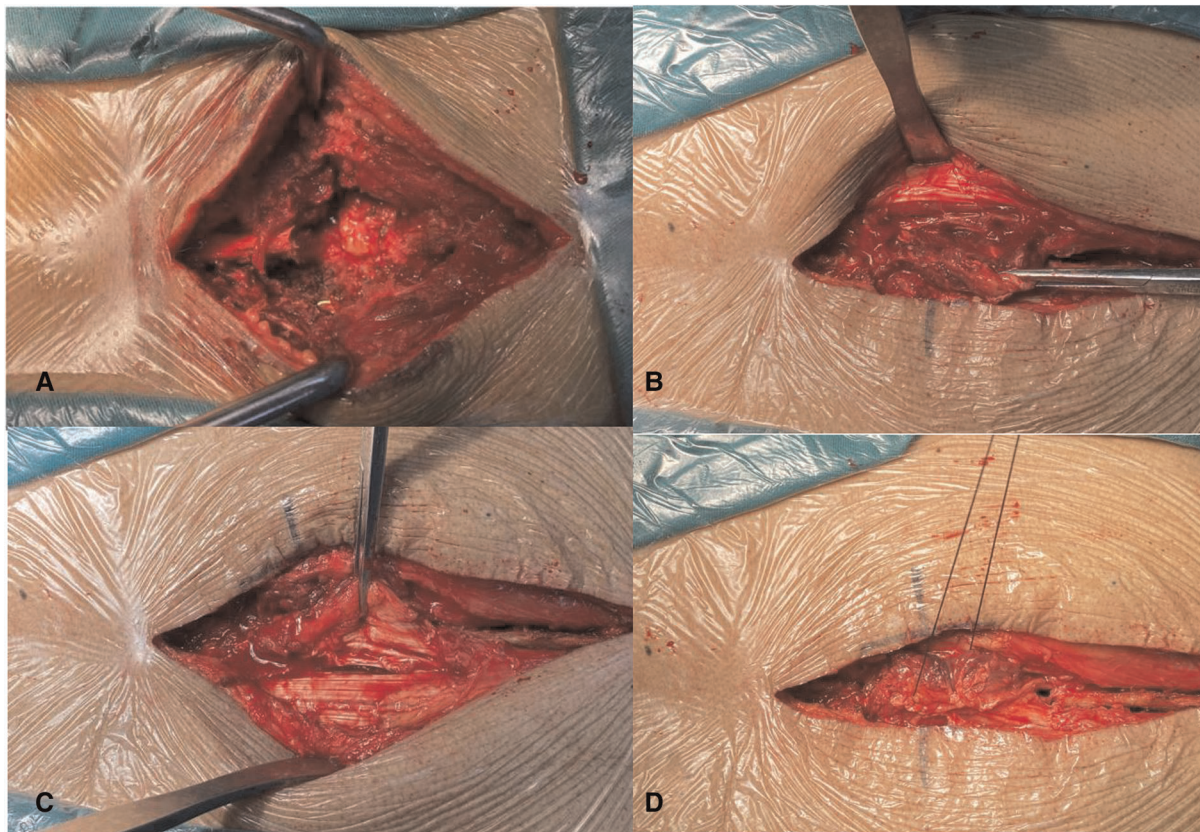


FIGURE 1

(A) A piece of autologous fat graft was used to shelter the dural gap; (B–D) paraspinous muscle flap was used for closing dead space of bilateral paraspinous muscles.

In our study, the main clinical symptom of CSF leak was postural headache caused by the low intracranial pressure. Therefore, visual analogue scale (VAS) score was used to evaluate the headache preoperatively, postoperatively (3 days after surgery), and in the last follow-up visit in case of onset of symptoms. The VAS scoring was conducted as follows: a line was divided into 10 pieces (0 for no pain; 10 for the most severe pain), and patients used a pen to describe the degree of the pain in the line.

Statistical analysis

In the present study, SPSS 22.0 software (IBM Corp., Armonk, NY, USA) was used to perform statistical analysis. $P < 0.05$ was considered statistically significant. According to the data distribution, the Student's *t*-test or the Mann–Whitney *U* test, as appropriate, was used for analysis of quantitative data in CS and FPM groups. The Chi-square test was used for analysis of qualitative data in CS and FPM groups. In each group, paired nonparametric test (Wilcoxon test) was utilized for comparing VAS score between postoperative and the last follow-up visit

data. In each group, the paired *t*-test was used for comparing JOA score among preoperative, postoperative, and the last follow-up visit data. According to the Bonferroni correction, *P*-value was corrected to 0.0167 for decreasing type 1 error.

Results

Table 1 compares patients' basic characteristics between CS and FPM groups. There was no statistically significant difference in age ($P = 0.561$), gender ($P = 0.609$), BMI ($P = 0.410$), follow-up time ($P = 0.878$), medical comorbidities, and smoking history ($P = 0.623$) between the two groups.

Three thoracic spine-related diseases and three lumbar spine-related diseases were involved in the study (**Table 2**). Thoracic disc herniation, ossification of posterior longitudinal ligament, and ossification of ligamentum flavum were diagnosed in 1 patient, 3 patients, 9 and 2 patients, 3 patients, 12 patients in CS and FPM groups, separately. Lumbar disc herniation, spinal stenosis and spondylolisthesis were diagnosed in 3 patients, 15 patients, 3 and 3 patients, 11

TABLE 1 Comparison of patient basic characteristics between group CS and group FPM.

| Variable | Total patients (n = 71) | Group CS (n = 34) | Group FPM (n = 37) | P-value |
|-------------------------|-------------------------|-------------------|--------------------|---------|
| Age (years) | 51.64 ± 11.92 | 50.76 ± 11.84 | 52.43 ± 12.10 | 0.561 |
| Gender | | | | 0.609 |
| Male | 25 | 13 | 12 | |
| Female | 46 | 21 | 25 | |
| Body mass index | 25.31 ± 3.55 | 24.93 ± 3.42 | 25.64 ± 3.67 | 0.410 |
| Follow-up period (m) | 15.10 ± 4.15 | 15.18 ± 4.11 | 15.03 ± 4.24 | 0.878 |
| Medical comorbidities | | | | |
| Hypertension | 26 | 13 | 13 | 0.786 |
| Diabetes | 14 | 5 | 9 | 0.309 |
| Cardiac disease | 17 | 9 | 8 | 0.632 |
| Cerebrovascular disease | 14 | 6 | 8 | 0.674 |
| Osteoporosis | 20 | 9 | 11 | 0.760 |
| Smoking | 21 | 11 | 10 | 0.623 |

patients, and 6 patients in CS and FPM groups, separately. The constituent ratio of diagnosis was not statistically different between the two groups ($P=0.813$). Four surgical methods, including laminal decompression, laminal decompression with pedicle screws, laminal decompression with nucleus pulposus enucleation, and ... were involved in the study, and there was no statistically significant difference between the two groups ($P=0.806$, Table 2). The average operation time ($P=0.248$) and intraoperative blood loss ($P=0.393$) were similar in CS and FPM groups (Table 2).

Location of dural tear was recorded in posterior, anterior, and lateral areas of dura mater (Table 3). In the CS group, posterior CSF leak was detected in 23 patients, as well as anterior CSF leak in 8 patients, and lateral CSF leak in 3 patients, in which dural suturing was performed on 24 (70.59%) patients. In the FPM group, posterior, anterior, and lateral CSF leak were observed in 19, 10, and 8 patients, respectively, and dural suturing was carried out on 21 (56.76%) patients. No statistically significant difference was found in the location of dural tear ($P=0.252$) and dural suturing ($P=0.227$) between the two groups. The average drainage tube time in the FPM group was 3.89 ± 1.17 days, which was shorter ($P<0.001$) than that (5.12 ± 1.56) in the CS group. The drainage volume in the FPM group (281.08 ± 284.76 ml) was also smaller ($P<0.001$) than that in the CS group (859.70 ± 553.11 ml).

In the CS group, 15 (44.11%) patients complained of postural headache, and postoperative VAS score was 4.13 ± 1.36 that reduced to 0.67 ± 1.05 at the last follow-up visit ($P=0.001$) (Table 4). Besides, 7 (18.91%) patients in the FPM group complained of postural headache, which was fewer than that in the CS group ($P=0.022$). The postoperative VAS score

TABLE 2 Diagnosis and surgical date in group CS and group FPM.

| Variable | Group CS (n = 34) | Group FPM (n = 37) | P-value |
|--|-------------------|--------------------|---------|
| Diagnosis | | | 0.813 |
| Thoracic | 13 | 17 | |
| Disc herniation | 1 | 2 | |
| Ossification of posterior longitudinal ligament | 3 | 3 | |
| Ossification of ligamentum flavum | 9 | 12 | |
| Lumbar | 21 | 20 | |
| Disc herniation | 3 | 3 | |
| Spinal stenosis | 15 | 11 | |
| Spondylolisthesis | 3 | 6 | |
| Surgical method | | | 0.806 |
| Lamina decompression | 3 | 5 | |
| Lamina decompression with pedicle screws | 12 | 14 | |
| Lamina decompression with nucleus pulposus enucleation | 1 | 2 | |
| Interbody fusion with pedicle screws | 18 | 16 | |
| Surgical time (min) | 161.21 ± 47.62 | 174.86 ± 50.09 | 0.248 |
| Intraoperative blood loss (ml) | 314.85 ± 129.08 | 341.08 ± 125.78 | 0.393 |

TABLE 3 Clinical date about CSF leakage in group CS and group FPM.

| Variable | Group CS (n = 34) | Group FPM (n = 37) | P-value |
|---|-------------------|--------------------|---------|
| Dural rupture location | | | 0.252 |
| Posterior | 23 | 19 | |
| Anterior | 8 | 10 | |
| Lateral | 3 | 8 | |
| Dural suture | | | 0.227 |
| Yes | 24 | 21 | |
| No | 10 | 16 | |
| Postoperative drainage tube time (days) | 5.12 ± 1.56 | 3.89 ± 1.17 | <0.001 |
| Postoperative drainage (ml) | 859.70 ± 553.11 | 281.08 ± 284.76 | <0.001 |
| Low intracranial pressure symptoms | 15 | 7 | 0.022 |
| Revision surgery | 2 | 0 | — |

in the CS group was 2.57 ± 0.98 , and it decreased to 0.29 ± 0.49 at the last follow-up visit ($P=0.016$) (Table 4). There was a statistically significant difference in postoperative VAS score ($P=0.013$) between the two groups, however, no statistically significant difference was noted in the last follow-up visit VAS score between the two groups ($P=0.507$). In both groups, postoperative and the last follow-up visit JOA scores were higher than those of preoperative JOA score (each

TABLE 4 Clinical outcomes in group CS and group FPM.

| Variable | Group CS (n = 34) | Group FPM (n = 37) | P-value |
|----------------|----------------------|-----------------------|---------|
| VAS (headache) | | | |
| Postoperative | 4.13 ± 1.36 | 2.57 ± 0.98 | 0.013 |
| Last follow-up | 0.67 ± 1.05* | 0.29 ± 0.49* | 0.507 |
| P-value | 0.001 | 0.016 | |
| JOA | | | |
| Preoperative | 12.03 ± 6.22 | 11.86 ± 6.25 | 0.912 |
| Postoperative | 16.06 ± 7.96* | 15.05 ± 7.81* | 0.595 |
| Last follow-up | 16.97 ± 7.76* | 16.51 ± 8.27* | 0.813 |

*Compared with preoperation, $P < 0.005$.

$P < 0.001$); however, between the two groups, no statistically significant difference was found in preoperative JOA score ($P = 0.912$), postoperative JOA score ($P = 0.595$), and the last follow-up visit JOA score ($P = 0.813$) (Table 4). It is noteworthy that the incision in 1 patient in the CS group was not healed until 14 days after surgery, and CSF continued to flow out of the incision, therefore, revision surgery was performed. Delayed meningeal cyst was found in another patient in the CS group at 1 month after surgery, and subcutaneous cystic structure was touched around incision area. In addition, revision surgery was performed on patients who still complained of postural headache.

Discussion

With the advent of an aging society, incidence of thoracolumbar disk disease is remarkably elevated. Thoracolumbar surgery is mainly complex, especially in the posterior approach, which is typically used to deal with complicated lesions or patients with a long course of disease. Ossification of the ligamentum flavum and calcification of the nucleus pulposus often result in adhesion to the dura, which can be easily damaged intraoperatively and lead to CSF leak. Thus, CSF leak is a common complication of thoracolumbar surgery that mainly occurs in the posterior approach (10–13). CSF leak was reported to occur in different incident rates in primary lumbar spine surgery versus revision surgery. Menon et al. (14) reported that the incidence of CSF leak in primary lumbar spine surgery ranged from 5.5% to 9%. Khan et al. (15) found that the incidence of dural tear in revision surgery was 15.9%, and this rate was 7.6% in primary lumbar spine surgery. Patients with CSF leak presented postural headache, continuous wound drainage, vertigo, posterior neck pain, etc. (1, 4). In the case of co-infection, meningitis may also occur, which is life-threatening (16). Tang et al. (16) demonstrated that timely dural repair greatly reduced the occurrence of complications and improved patients' prognosis. However, in

the large dural defect, the silk suture could not be used alone, and the suture itself also caused new dural holes, which increased the damaged dural area to some extent (8). Therefore, it is essential to clarify the method of dural repair and materials that could be used for dural repair, so as to improve patients' prognosis.

A great number of methods were proposed to manage a dural tear. A study used bed rest only in the treatment of patients with CSF leak, and achieved satisfactory results (4). Hughes et al. (17) used Jackson-Pratt drainage to treat 8 patients with CSF leak, and those patients did not undergo dural repair. A promising prognosis was observed, all patients were discharged on time, and there was no complication associated with the long-term drainage tube (17). This might be related to the abundance of blood vessels in the dura, providing a strong ability to repair itself (18). Therefore, without surgical treatment, only conservative treatment is also effective for repairing dural tears. However, surgeons mainly preferred to repair the ruptured dura intraoperatively to achieve better results. Zhao et al. (19) also showed that the incidence of postoperative CSF leak was reduced by 5%–9% after intraoperative surgical treatment. Therefore, it is necessary to actively carry out intraoperative dural repair. Various materials can be used to repair dural tears, such as gelatin sponge, artificial dura, fibrin glue, fat graft, etc. (20). However, using different methods may cause different outcomes. In general, autologous fat/muscle/fascia tissue or gelatin sponge were mainly used for repairing dural tears (21). An autologous fat/muscle/fascia graft could be economic, with no rejection reaction, while it was difficult to achieve a tight waterproof (20, 22). A fat tissue can only play an anti-adhesion role in the early stage. The remaining fiber skeleton can be adhered to the surrounding tissue, forming a scar tissue when lipid droplets disappear at middle and late stages (23). However, a previous study (24) pointed out that the use of a fat graft caused complications of cranial fat dissemination. Therefore, some surgeons used gelatin sponges to repair the dural tears. As early as 1995, Narotam et al. (25) found that gelatin sponges promoted fibroblast activity, accelerated the dural regeneration, and had satisfactory clinical effects on preventing spinal nerve root adhesion. Tong et al. (26) demonstrated that hematopoietic stem and progenitor cells (HSPCs) could be enriched by implanting biomaterials into spatium intermusculare, which could be beneficial for patients' recovery. However, Buyuktepe et al. (27) reported a case of acute hydrocephalus due to application of gelatin sponges, and it was revealed that CSF flow was immediately restored after removing this material, in which an additional ventriculostomy was performed. There is no clear conclusion to indicate which material is more appropriate for the treatment of CSF leak.

In our study, the method of using paraspinal muscle flap combined with fat graft for repairing CSF leak showed

satisfactory clinical outcomes. Posterior dural tear was easy to suture, however, anterior and a part of lateral tear were sometimes difficult to suture. Intraoperative immediate suturing plays an important role in the reduction of the drainage volume. In the case of failure of dural suturing, more CSF could be leaked from the dura mater. Under this condition, paraspinal muscle flap combined with fat graft showed to be advantageous in decreasing postoperative drainage volume. There are viable adipose-derived stem cells, which might be differentiated into cellular structures required during dural repair (28, 29). In addition, bilateral paraspinal muscle flap eliminated the dead space of incision. Using these methods, postoperative drainage tube time or postoperative drainage volume could be significantly decreased. With the treatment of CSF leak, the incidence and the degree of postural headache were also significantly reduced. The method proposed in the current study showed promising results, particularly for the occurrence of CSF leak during posterior thoracolumbar surgery.

The present study evaluated the efficacy of utilizing fat graft combined with paraspinal muscle flap to treat CSF leak during posterior thoracolumbar surgery, however, there were several limitations that should be pointed out. First, the study was limited by its retrospective nature, and it was a single-center study with a small sample size. Second, no special biomaterials were included in the surgery. This could be related to the fact that there are numerous types of biomaterials for dural repairing, which could influence the accuracy of the surgery. Third, this study only included patients who underwent the primary lumbar spine surgery, and those who underwent the revision surgery were not involved. Factors influencing clinical outcomes in the revision surgery and the intraoperative situation should be explored. In addition, in the revision surgery, muscle tissue is replaced with scar tissue with varying degrees, thus, the proposed method is not always applicable.

Conclusion

Fat graft combined with paraspinal muscle flap could be an effective method to treat CSF leak during posterior thoracolumbar surgery. The proposed method significantly reduced postoperative drainage tube time and postoperative drainage volume. It also decreased the incidence and the

degree of postural headache. The proposed method showed satisfactory clinical outcomes, and it is worthy of promotion.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

XG and PD are responsible for the integrity and authenticity of this work, conception and design, and writing and critical revision of the article. JX and JS: literature research. XG and PD: data extraction. XG and PD: data analysis. WD and D-LY: give guidance and advice. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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