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HOW I DO IT

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Total Hilar Exposure Maneuver for Repair of Complex Bile Duct Injury

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Abstract

The reconstruction of high-level bile duct injury is challenging because exposure of the hilar area is limited and sometimes inaccessible by the Hepp–Couinaud approach. We describe a maneuver for total hilar exposure to perform complex bile duct injury reconstruction. After adhesions surrounding the liver are divided, intraoperative ultrasonography is used to delineate the hilar and intrahepatic biliary anatomy. Surgical exposure of the biliary system is achieved by our maneuver, which consists of four steps: (1) identification of landmark structures, such as the base of the umbilical fissure, the inferior edge of segment 4b, the cystic-hilar plate junction, and the right anterior portal pedicle; (2) lowering of the hilar plate; (3) hepatotomy along the right anterior pedicle; and (4) connection of the hepatotomy to the base of segment 4b. This maneuver allows the liver to be flipped upward, which facilitates clear exposure of the hilar duct and preserves the liver parenchyma. The anterior parts of the right and left hepatic duct are then opened, a wide-hepaticojejunostomy anastomosis is achieved for biliary reconstruction, and a jejunal subcutaneous limb is created. We used this maneuver for treating complex bile duct injury in six cases; none of the patients has died, and two had Clavien–Dindo grade III complications, including surgical site infection and intra-abdominal collection. The total hilar exposure maneuver is thus feasible and safe. It provides excellent exposure of both hepatic ducts and is a good surgical alternative to the Hepp–Couinaud approach in cases of high-level injury.

KEYWORDS

bile duct injury, biliary reconstruction, surgical exposure, surgical technique, treatment

1 | INTRODUCTION

The incidence of bile duct injury (BDI) has decreased since the introduction of laparoscopic cholecystectomy.[1] When it occurs, BDI affects quality of life and can be fatal.[1] In addition, vascular injuries concomitant with BDI may result in liver failure, which necessitates hepatectomy and liver transplantation.[2] On the other hand, in the absence of indications for hepatectomy, high-quality biliary reconstruction is crucial. Surgical exposure of the extrahepatic part of the left hepatic duct (LHD), the so-called Hepp–Couinaud technique,[3] has been proposed as part of a safe, highly effective treatment of biliary stricture. The Hepp–Couinaud technique, although excellent

for LHD exposure, provides only limited exposure of the right hepatic duct (RHD).[4] Therefore, repairing the high-level biliary injury may be difficult, resulting in a short bilioenteric anastomosis with subsequent development of anastomosis stricture. In this study we report a surgical technique for complex biliary injury reconstruction, the total hilar exposure maneuver, which provides excellent exposure of the RHD and LHD.

2 | PATIENTS AND METHODS

2.1 | Patients

We retrospectively reviewed the medical records of patients who underwent surgical reconstruction for BDI at our institution from June 2019 to May 2021. Our protocol of preoperative imaging evaluation includes computed tomography of the liver in all cases (Figure 1A) and one or more of the following modalities: cholangiography, magnetic resonance cholangiopancreatography, percutaneous transhepatic cholangiography, and endoscopic retrograde cholangiography (Figure 1B–D). Patients' clinical conditions such as sepsis, cholangitis, intra-abdominal collection, and malnutrition were optimized preoperatively in all cases. The injury was documented according to the classification by Strasberg et al.[5] Preoperative and intraoperative indications for which the maneuver is especially useful are summarized in Table S1. Postoperative follow-up consisted of clinical and blood chemistry examinations every 1–3 mo for up to 1 y and every 6 mo thereafter. Postoperative imaging was performed only if clinically indicated. Primary patency was evaluated regularly until the last follow-up visit.

We defined primary patency after the completion of the index surgical treatment as the condition of the duct that involved no episode of cholangitis, jaundice, liver abscess, or external biliary fistula, freedom from stents, and freedom from invasive interventions.[6] Criteria for judging injury to a vascular structure were defined according to the report by Strasberg and Helton.[7]

2.2 | Surgical technique

With the patient in the supine position, the laparotomy is performed through a mirror L-shaped incision. We divide the abdominal adhesions surrounding the liver and hepatic hilum (Figure S1A), taking care not to injure surrounding organs. We apply an abdominal retractor (Omni-tract, St. Paul, MN) and then encircle the hepatoduodenal ligament with umbilical tape for use as a landmark, but we perform no dissection in this area (Figure S1B). The detail of navigation technique and technical point of dissection are summarized in Table S2. If a bilioenteric fistula is present (Figure 1C), it is repaired at this step. Intraoperative ultrasonography (IOUS) is then used to delineate the hilar and intrahepatic biliary anatomy, along with Doppler imaging of hepatic arterial flow to the liver (Video S1–S3). This step is essential for identifying landmark structures and for ensuring blood supply to the liver and bilioenteric anastomosis. We did not attempt

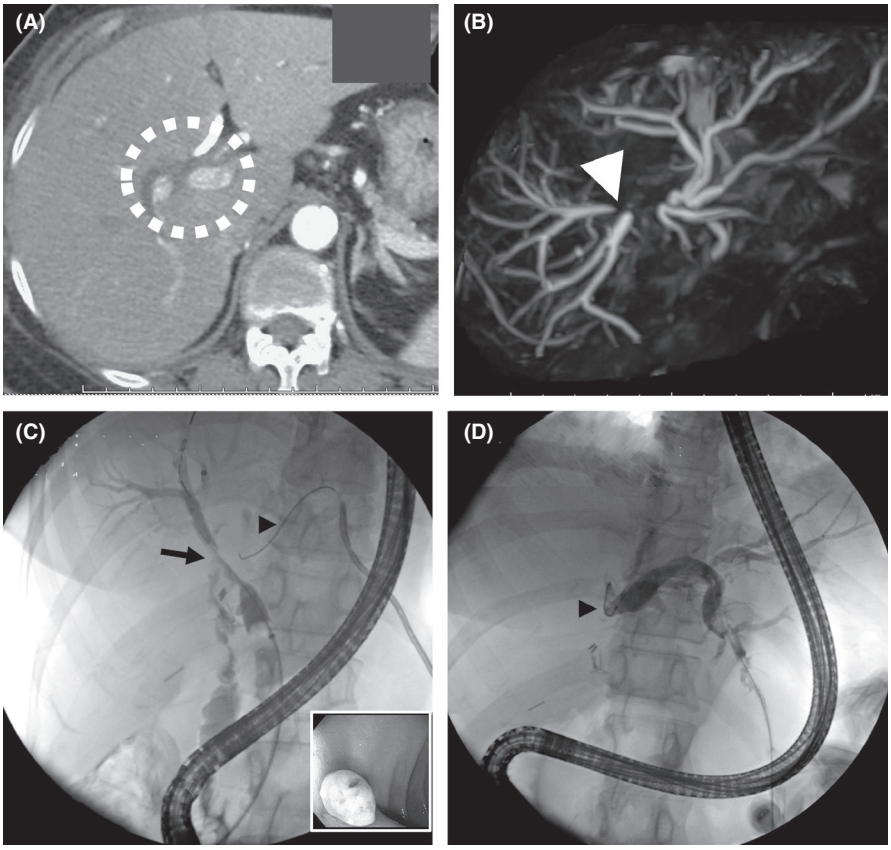

FIGURE 1 Preoperative imaging evaluation. (A) Computed tomography of the liver showed injury to the right hepatic artery (circle) with distal reconstitution. (B) Magnetic resonance cholangiography showed E4 injury with noncommunication of the right anterior and posterior ducts (white arrow). (C) Endoscopic retrograde cholangiography with percutaneous cholangiography (PTC) revealed a bilioenteric fistula extending to the duodenum (black arrow) and a wire in the left hepatic duct (LHD) (arrowhead). (D) PTC showed noncommunication of the LHD (arrowhead) with the right hepatic duct and an E4 injury

vascular reconstruction in the delayed biliary repair. In this strategy, the biliary necrosis is likely to reach the stable state with adequate hilar arterial shunt (Figure S2).

To expose the total hilar region, we use four steps: (1) identification of landmark structures (Figure 2A), such as the base of the umbilical fissure, the inferior edge of segment 4b, cystic-hilar plate junction, and the right anterior pedicle (RAP); (2) lowering of the hilar plate from the base of the umbilical fissure to the cystic-hilar plate junction (Figure 2B); (3) performing hepatotomy along the RAP up to the hepatic surface (Figure 2C) or the midway, depending on the level of bile duct exposure desired; and (4) performing hepatotomy in the caudocranial direction along the left side of the middle hepatic

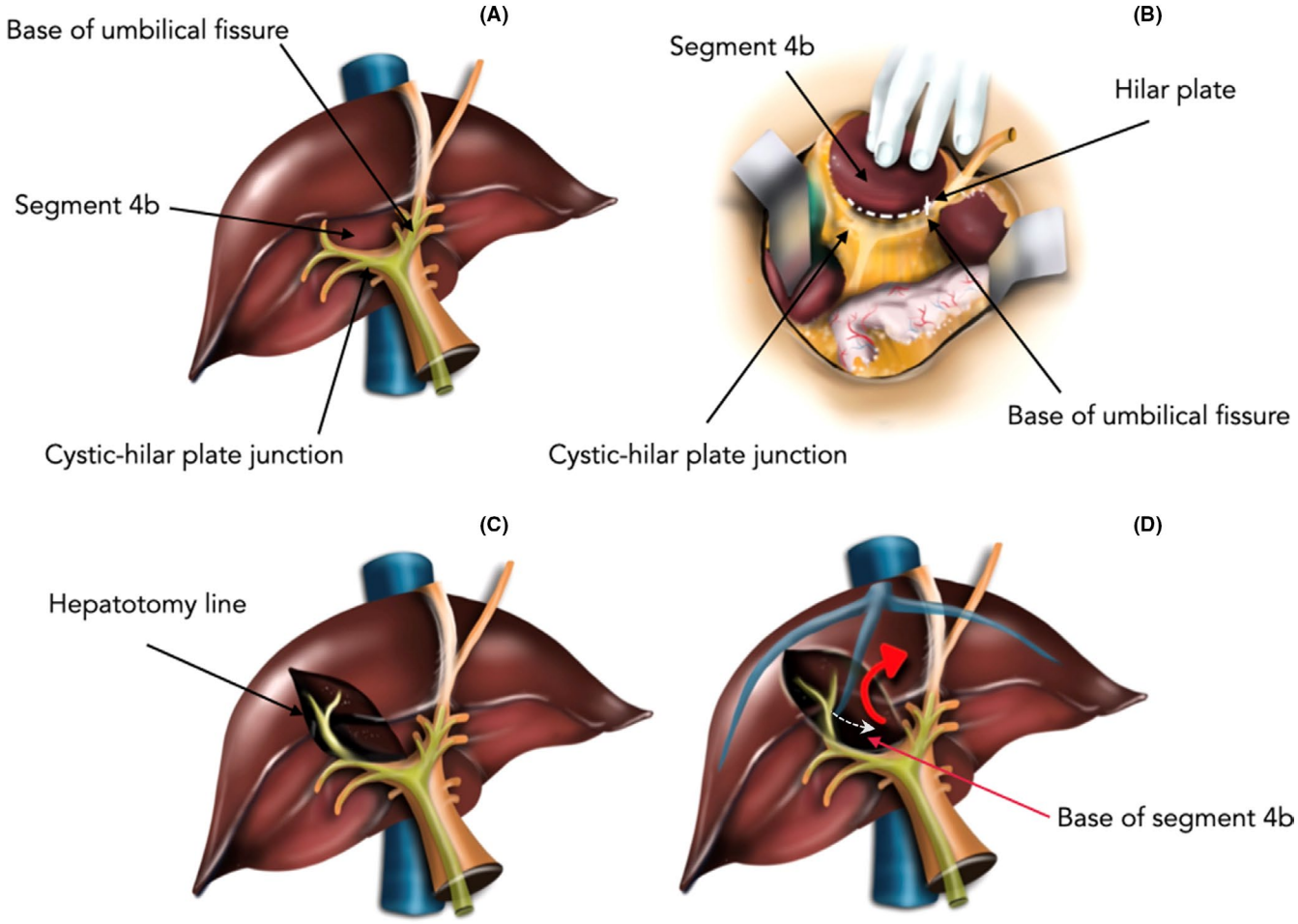

FIGURE 2 Schema of the total hilar exposure maneuver. (A) Step 1: Identifying landmarks; hilar bile duct located between the base of umbilical fissure and cystic-hilar plate junction, the hilar plate located below the inferior edge of segment 4b, and right anterior pedicle (RAP) located posteriorly to the cystic-hilar plate junction. (B) Step 2: Lowering of the hilar plate along the hilar bile duct by opening the peritoneum at the base of segment 4b. (C) Step 3: Performing hepatotomy along the RAP up to hepatic surface. (D) Step 4: Connecting the hepatotomy (white arrow) to the base of segment 4b and completely exposing the total hilar

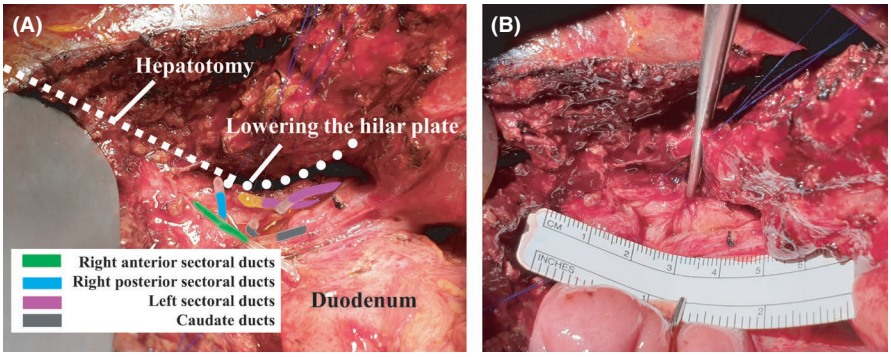

FIGURE 3 Intraoperative photographs after the total hilar exposure maneuver. (A) Pediatric feeding tubes are inserted into all bile duct openings, which are identified on intraoperative ultrasonography. (B) Exposure of the left and right hepatic ducts

vein to the base of segment 4b (Figure 2D). Using either the clamp crushing technique or the Cavitron Ultrasonic Surgical Aspirator (CUSA Excel, Integra Lifesciences, Plainsboro, NJ), we then dissect the liver. During the third step, several sub-centimeter third- or fourth-order branches of the RAP may need to be sacrificed. The fourth step allows the liver to be flipped up, which fully exposes the hilar duct and preserves the liver parenchyma (Video S4, Figure S3).

We then confirm the position of the bile duct by obtaining bile content through needle aspiration, and the sample is sent for culture. Next, we open the anterior part of the bile duct along the LHD to the right anterior duct by using port scissors; during this step, we control bleeding from small arteries within the bile duct wall with isolated 5-0 absorbable sutures. Pediatric feeding tubes are inserted into all bile duct openings (Figure 3A), which are identified on IOUS. Then, the retrocolic jejunum is prepared in a tension-free manner for Roux-en-Y hepaticojejunostomy (HJ) anastomosis. When the gap between the RHD and LHD is identified, we decide whether to perform ductoplasty with a single HJ anastomosis (the preferred method) or with two separated HJ anastomoses. The total length of the duct is measured after total hilar exposure and prepared for anastomosis (Figure 3B). To establish the side-to-side HJ anastomosis, we use a 5-0 absorbable monofilament suture in an interrupted knot-outside manner. Transanastomotic stents have not been used in our patients. The end-to-side jejunojejunostomy is completed 50 cm away from the HJ anastomosis. The jejunum subcutaneous limb is brought up in the upper abdomen. The closed suction abdominal drain is routinely placed near the anastomosis, and the abdominal cavity is closed.

3 | RESULTS

Six patients have undergone the total hilar exposure maneuver for complex biliary reconstruction. All the patients were women, with a mean age of 42 y. All cases of BDI were diagnosed on a median of 6 d after surgery. Bile leakage and peritonitis were the most common manifestations of BDI. All but one patient had undergone primary surgery with a laparoscopic approach. Three patients had E4 injury according to the classification by Strasberg et al[5]; four had right hepatic artery injury, and two had spontaneous bilioenteric fistula involving the first part of the duodenum. For previous treatment, three patients had undergone exploratory laparotomy for either drainage collection or suturing repair of bile leakage, and four patients needed biliary drainage due to cholangitis. All patients underwent delayed repair of biliary injury without vascular reconstruction, at a median of 158 d after primary surgery. Multimodality cholangiography was used in all patients.

The baseline characteristics of patients are summarized in Table 1. In terms of the operative outcome of the total hilar exposure maneuver, the length of HJ anastomosis ranged from 3 to 6 cm. Two patients needed two separated HJ anastomoses. Two patients had grade III postoperative complications according to the Clavien–Dindo classification; one had a surgical site infection that necessitated surgical debridement, and the other had an intra-abdominal collection, which was successfully treated with drainage under radiological guidance and intravenous antibiotics. None of our patients died. All patients achieved primary patency by a median follow-up time of 12 mo (Table 2). One patient underwent successful repair of E4 injury and noncommunication of the right anterior and posterior bile ducts.

4 | DISCUSSION

The total hilar exposure maneuver is feasible and safe for complex BDI reconstruction. This surgical technique provides excellent exposure of both the RHD and LHD, and thus, it is applicable to repair high-level injury. Moreover, E4 injury associated with vascular injury is amenable to this maneuver, and a good short-term outcome was demonstrated by the achievement of primary patency.

TABLE 1 Baseline characteristics

Characteristics	Total (N = 6)
Gender	
Male	0
Female	6
Age, y (median)	42 (range, 30–62)
Time of recognition	
Intraoperative diagnosis	0
Postoperative diagnosis, d (median)	6 (range, 1–150)
Presentations (%)	
Bile leakage only	33.3
Bile leakage with bleeding	16.7
Obstructive jaundice	16.7
Peritonitis	33.3
Injury-related data	
Laparoscopic approach	5
Open approach	1
Classification by Strasberg et al[5]	
E3	3
E4	3
RHA injury (%)	66.7
Bilioenteric fistula (%)	33.3
Previous treatment (%)	
Exploratory laparotomy	50
Biliary drainage	66.7
Injury-to-repair time, d (median)	158 (range, 61–339)
Preoperative imaging	
CT of liver	6
MRCP	5
PTC	4
ERCP	3
Length of follow-up, mo (median)	12 (range, 3–23)

Abbreviations: CT, computed tomography; ERCP, endoscopic retrograde cholangiopancreatography; MRCP, magnetic resonance imaging; PTC, percutaneous cholangiography; RHA, right hepatic artery.

TABLE 2 Operative management and outcome

Case	Injury type[a]	Vascular injury	Hepatotomy	Lowering of hilar plate	Creation of subcutaneous jejunal limb	Total length of HJ (cm)	No. of HJs	Clavien–Dindo grade at 30 d	Achievement of primary patency
1	E3	RHA	Short[b]	Yes	Yes	3	1	None	Yes
2	E3	RHA	Short	Yes	Yes	3	1	None	Yes
3	E4[c]	RHA	Long[d]	Yes	Yes	3.5	2	III	Yes
4	E4	None	Long	Yes	Yes	6	2	None	Yes
5	E3	LPV	Long	Yes	Yes	4	1	III	Yes
6	E4	RHA	Long	Yes	Yes	5	1	None	Yes

Abbreviations: HJ, hepaticojejunostomy; LPV, left portal vein; RHA, right hepatic artery.

[a]Injury type was classified according to the classification by Strasberg et al.[5]

[b]Short hepatotomies extended from the middle of the hilum to the hepatic surface.

[c]No communication of right anterior and posterior bile duct.

[d]Long hepatotomies extended from the hilum to the hepatic surface.

Reported series of surgical treatments for postcholecystectomy biliary stricture demonstrated good long-term outcomes in patients with E3 or E4 injuries associated with vascular injury that were treated with liver resection.[8] The indications for hepatectomy include E3 or E4 injury with vascular injury, ipsilateral liver atrophy, recurrent cholangitis, and stricture of prior HJ anastomosis. However, hepatectomy in the treatment of complex BDI is associated with significant rates of morbidity (up to 60%).[2,9] In addition, it increases the risk of posthepatectomy liver failure. Therefore, hepatectomy should be reserved for carefully selected cases.

The problem with biliary reconstruction after high-level injury is the limited exposure of the hilar area. Some authors have demonstrated favorable long-term outcomes with the use of Hepp–Couinaud HJ.[10,11] A report of surgical reconstruction demonstrated a 92% success rate with Hepp–Couinaud HJ in repairing E1 to E4 injury.[11] However, most patients with E4 injury in the series were treated with liver transplantation. In fact, only one patient with E4 injury was successfully treated with this technique.

An alternative approach for biliary reconstruction for complex BDI has been reported[12,13]: the partial resection of segment IV/V. Mercardo et al[14] reported successful repair of complex biliary injury with this technique. They emphasized that this technique provided better exposure to the hilar area than did the Hepp–Couinaud technique. Mercardo et al[15] also reported good long-term results after reconstruction by partial resection of segment IV/V, with a low rate of anastomosis stricture. However, the patients with E4 injury were excluded from their study. Possible reasons for the successful outcome are probably related to better surgical exposure, with which wide and precise mucosa-to-mucosa anastomosis of healthy biliary tissue could be performed. Another advantage was that the rich blood supply of the bile duct (the epicholedochal venous plexus) prevented the development of anastomosis stricture.[7] Although this technique has several advantages over the conventional Hepp–Couinaud method, its use was limited to the approach to the LHD; thus, the ductotomy was sometimes less than 1.5 cm long. In such cases, the RHD needed to be opened to create a wider anastomosis.[16]

The RHD approach in biliary reconstruction was proposed by Strasberg et al.[17] The indications included E4/E5 injuries and a short LHD in E3 injury.[16] According to Strasberg et al,[17] the procedure consisted of dissection of the plane between the right portal pedicle and liver parenchyma and then resection of the liver parenchyma above the pedicle. Although this technique could be used to approach the RHD, liver resection was necessary, and sometimes exposure was inadequate due to the shortness of the RHD. In our technique, in contrast, both extrahepatic and intrahepatic parts of the RHD up to the sectoral ducts could be reached with preservation of the parenchyma. In this series, we were able to approach the sectoral ducts in cases of E4 injury, even when the right anterior and posterior ducts had no communication. Moreover, due to the excellent exposure of the RHD, this technique could be applied to cases of E3 injury with a short LHD.

Brown et al reported that duct shortness was significantly associated with the development of stricture.[18] However, no standard length of HJ anastomosis can be recommended at this time due to the scarcity of evidence. On the other hand, the shortness of the anastomosis close to the injury site may lead to scarring, poor blood supply to tissue, and possibly a poor long-term outcome. In addition, any failure of an attempted repair is associated with a worse prognosis.[19] The created anastomosis should be as long as possible. Therefore, the total hilar exposure maneuver is probably the best approach in cases of high-level BDI.

The rate of complications after biliary repair of BDI was reported to be ~34%–52%.[20,21] The vasculobiliary injury was the independent risk factor for treatment failure.[22] In our series, two patients (33.3%) had Clavien–Dindo grade III complications, but the mortality rate was zero. These findings are comparable with the morbidity rate reported by Holte et al[21] and the low mortality rate reported by Buell et al.[23] Although our patients had sustained the injury, all of them achieved primary patency, with a median follow-up of 12 mo. However, this short follow-up period after using this technique in surgical repair is the limitation of our study. Hence, long-term follow-up is needed to evaluate the long-term patency of this novel technique.

The total hilar exposure maneuver is feasible and safe. It provides excellent exposure of both the RHD and LHD and is a good alternative to the Hepp–Couinaud approach in cases of high-level injury. The

long-term efficacy of this new surgical technique warrants further study.

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DISCLOSURE

Ethical Approval: The study was approved by the Review Board of Songklanagarind Hospital, Prince of Songkla University (approval no. REC.64-288-10-1) and it conforms to the provisions of the Declaration of Helsinki.

Informed Consent: Informed consent was obtained from all the patients.

Registry and the Registration No. of the study/trial: not applicable.

Animal Studies: Not applicable.

Conflict of Interest: The authors declare no conflicts of interest for this article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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