Migration of fully covered self-expandable metallic stents used to treat anastomotic strictures after orthotopic liver transplantation
A single-center, retrospective analysis

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Abstract
Insertion of a fully covered self-expandable metallic stent (FCEM) through endoscopic retrograde cholangiopancreatography is an effective solution for biliary anastomotic stricture following orthotopic liver transplantation (OLT). However, FCEM migration continues to plague patients. This study aimed to evaluate the FCEM migration rate in our center, and to investigate the factors increasing the migration risk for FCEM.

The study enrolled 43 post-OLT patients with confirmed duct-to-duct AS. The effects of age, gender, albumin, alanine aminotransferase, aspartate aminotransferase (AST), γ-glutamyl transpeptidase, alkaline phosphatase, total bilirubin, direct bilirubin, ABO (blood group system consists of four antigens) incompatibility, stricture length, FCEM brand, FCEM length, donor liver and recipient bile duct diameters, size mismatches between the donor and recipient bile ducts >2 mm, diabetes and/or hypertension status, endoscopic sphincterotomy status, the use of plastic stents or nasobiliary drainage prior to FCEM implantation, duration from OLT to FCEM placement, and OLT etiology on FCEM migration were retrospectively analyzed.

The FCEM migration rate was 48.8% (21/43) at 6 months. The serum AST level was significantly higher in the migration group than that in the nonmigration group (52.48 vs 29.50 U/L, P < .05). A lower serum AST level was associated with a decreased risk of FCEM migration in post-OLT patients with duct-to-duct anastomotic stricture (hazard ratio = 0.968, 95% confidence interval: 0.940–0.996, P = .028).

In this single-center, retrospective cohort study, we showed that an elevated serum AST level was a potential risk factor for FCEM migration.

Abbreviations: AKP = alkaline phosphatase, ALT = alanine aminotransferase, AS = anastomotic stricture, AST = aspartate aminotransferase, DB = direct bilirubin, ERCP = endoscopic retrograde cholangiopancreatography, EST = endoscopic sphincterotomy, FCEM = fully covered self-expandable metallic stent, GGT = γ-glutamyl transpeptidase, OLT = orthotopic liver transplantation, PBS = plastic biliary stent, TB = total bilirubin.

Keywords: anastomotic stricture, aspartate aminotransferase, endoscopic retrograde cholangiopancreatography, fully covered self-expandable metallic stent, orthotopic liver transplantation

1. Introduction
The first orthotopic liver transplantation (OLT) was performed in 1963 by Dr. Thomas E Starzl[1] from the Denver Veterans Administration Hospital in the United States. At that time, the rate of mortality after OLT was high. Half a century later, OLT has become the principal treatment for end-stage liver diseases, including liver cancer, due to continuous improvements in surgical techniques and the availability of new antirejection drugs. However, biliary complications post-OLT persist, and are a major cause of death in adult recipients (11.5%–34%).[2–4]

Biliary complications include anastomotic strictures (AS), bile leakage, biloma, stones, sludge, biliary cast syndrome, sphincter of Oddi dysfunction, cholangitis, and hemobilia. AS is the most common problem, which develops in 4% to 9% of OLT patients.[5] Endoscopic retrograde cholangiopancreatography (ERCP) is the first-line post-OLT treatment for duct-to-duct AS.[6] Repeat placement of plastic biliary stents (PBSs) every 3 months for 1 year was the classic precaution against AS post-OLT. Currently, AS dilation via fully covered self-expandable metallic stent (FCEM) insertion is an established alternative.[7–9]

Compared to repeat PBS placement, FCEM insertion is associated with higher resolution rates (over 80%).[10] In addition, in a previous study, the number of ERCPs performed,
treatment duration, and costs were lower in the FCEM group than the PBS group.\(^6\) However, stent migration may occur in 0% to 41% of cases treated via FCEM placement.\(^7\)

To better treat post-OLT AS, there is an urgent need to define risk factors for FCEM migration. In this study, we aimed to determine these related factors.

2. Materials and methods

2.1. Patients

The present study was approved by our institutional ethics review board (approval no.: 2020017). The inclusion criteria were FCEM insertion in our hospital and OLT recipients aged \(\geq 18\) years without graft rejection. Patients were excluded if follow-up care was <6 months after FCEM insertion (n = 2), AS was combined with ischemic cholangiopathy (n = 4), OLT was performed not in our hospital (n = 4), patients with post-transplant lymphoproliferative disorders (n = 1), or active removal of FCEMs (n = 8) due to ERCP-related pancreatitis or cholangitis. Finally, we enrolled 43 post-OLT (cadaveric liver transplant) patients with confirmed duct-to-duct AS who underwent endotherapy between January 2017 and April 2019.

2.2. Protocol for FCEM placement and follow-up

At our center, magnetic resonance cholangiopancreatography revealing a biliary stricture at the anastomotic site, combined with abnormal liver blood test results (such as elevated serum levels of bilirubin, \(\gamma\)-glutamyl transpeptidase [GGT], alanine aminotransferase [ALT], aspartate aminotransferase [AST], and/or alkaline phosphatase [AKP]), often trigger a diagnosis of post-OLT AS. The preferred length of the FCEM above the AS was about 1 to 1.5 cm (case presentations are shown in Fig. 1). No patients underwent balloon dilation or percutaneous intervention. There was no case of insertion of a PBS inside a FCEM. Patients underwent surveillance with abdominal color Doppler ultrasound at 1 month after FCEM insertion. At 3 months and 6 months, patients underwent surveillance with abdominal color Doppler ultrasound combined with abdominal computed tomography or magnetic resonance cholangiopancreatography. The definition of stent migration was that the FCEM had partially slipped out below the AS but was still indwelling in the bile duct, or that the FCEM had slid completely out of the bile duct and was discharged from the intestine. The stent migration rate at 6 months after FCEM insertion served as the endpoint.

Figure 1. Case presentations. A) Stent migration case. B) Stent nonmigration case.
2.3. Explored factors
We analyzed the effects of age, gender, ABO incompatibility, diabetes and/or hypertension status, endoscopic sphincterotomy (EST) status, PBS placement or nasobiliary drainage prior to metallic stent implantation, the FCEM brand (Boston M00570530/M00570540, Niti-S BS1006F/BS1008F, or ENDO-FLEX BIL-1-10-80-RP), FCEM length, a size mismatch between the donor and recipient bile ducts >2mm, the OLT etiology, duration from the day of OLT to the day of FCEM placement, stricture length (measured by comparing it to the transverse diameter evident on duodenoscopy after contrast agent was injected into the bile duct), the level of serum albumin, ALT, AST, GGT, AKP, total bilirubin (TB), and direct bilirubin (DB) (liver biochemical tests 1 day before ERCP) on FCEM migration.

2.4. Statistical analysis
Statistical analyses were performed using the Statistical Package for Social Sciences for Windows version 19 (IBM, Armonk, NY). The chi-square test was used to compare categorical variables and Student t tests or a nonparametric test was employed to compare numerical variables. Binary logistic regression testing was used to derive risk factors. A P-value <.05 was taken to reflect significance.

3. Results
3.1. Comparison of categorical variables between the migration and nonmigration groups
In the present study, FCEM migration was evident in 21 (48.8%) cases, which were all found during a routine review. There were no significant differences in gender, ABO incompatibility, FCEM length, size mismatches between the donor and recipient bile ducts >2mm, diabetes and/or hypertension status, using of plastic stents or nasobiliary drainage prior to metallic stent implantation, or OLT etiology between the migration group and the nonmigration group (Table 1). However, Niti-S FCEM did not seem to slip easily. Of the 23 patients given Niti-S FCEMs, 7 became displaced; of 18 patients who received Boston FCEMs, 12 became displaced; of the 2 patients who received ENDO-FLEX FCEMs, both became displaced (Table 1). Somewhat more unexpectedly, the proportion of patients who underwent EST was significantly lower in the migration group than that in the nonmigration group (6/21 vs 13/22) (Table 1, P < .05).

3.2. Comparison of numerical variables between the migration and nonmigration groups
The serum AST level was significantly higher in the migration group than in the nonmigration group (52.48 vs 29.50 U/L) (Table 2, P < .05). In addition, ALT was significantly higher in the migration group than in the nonmigration group (66.52 vs 34.59 U/L) (Table 2, P < .05). However, there were no significant differences in the patients’ age, AS length, diameters of the donor

| Table 1 |
|---------|
| Summarized categorical variables of the migration group and the nonmigration group. |
| Total, n=43 | Migration group, n=21 | Nonmigration group, n=22 |
| Gender (male) | 32 | 15 | 17 |
| ABO incompatibility (yes) | 3 | 1 | 2 |
| Diabetes and/or hypertension (yes) | 12 | 6 | 6 |
| Nasobiliary drainage or PBS before FCEMs placement (yes) | 32 | 18 | 14 |
| Sphincterotomy (yes) | 19 | 6 | 13 |
| Length of FCEMs | | | |
| 6 cm | 17 | 7 | 10 |
| 8 cm | 26 | 14 | 12 |
| FCEMs brand | | | |
| Boston biliary uncovered stent | 18 | 12 | 6 |
| Niti-S biliary uncovered stent | 23 | 7 | 16 |
| ENDO-FLEX Biliary uncovered stent | 2 | 2 | 0 |
| Size mismatch between donor and recipient bile duct >2 mm (yes) | 14 | 8 | 6 |
| Etiology of OLT | | | |
| Nonmalignancy | 20 | 7 | 13 |
| Hepatitis B virus | 9 | 1 | 8 |
| Alcohol | 3 | 1 | 2 |
| Alcohol with hepatitis B virus | 1 | 0 | 1 |
| Wilson | 1 | 1 | 0 |
| Cholestasis | 1 | 1 | 0 |
| Caroli disease | 1 | 1 | 0 |
| Intrahepatic bile duct stones | 1 | 0 | 1 |
| Hepatic veno-occlusive syndrome | 1 | 1 | 0 |
| Severe drug-induced hepatitis | 1 | 1 | 0 |
| Schistosomiasis | 1 | 0 | 1 |
| Malignancy | 23 | 14 | 9 |
| Hepatocellular carcinoma | 20 | 13 | 7 |
| Cholangiocarcinoma | 3 | 1 | 2 |

FCEM = fully-covered self-expandable metallic stent, OLT = orthotopic liver transplantation, PBS = plastic biliary stent.
and recipient bile ducts, the duration from the day of OLT to the day of FCEM placement, and the serum levels of albumin, GGT, AKP, TB, and DB between the migration group and the nonmigration group (Table 2, P > .05).

### 3.3. Identification of risk factors related to FCEM migration

In the univariate analysis, factors that were related to an increased rate of FCEM migration in patients with biliary AS following OLT included a higher serum AST level and EST nonperformance (P < .05). However, the binary logistic regression analyses indicated that only a lower serum AST level was associated with a decrease in the risk of FCEM migration (hazard ratio = 0.968, 95% confidence interval: 0.940–0.996, P = .028) (Table 3).

### 4. Discussion

A biliary stricture is the most common biliary complication after OLT.\(^{[11]}\) AS occurs in 4% to 9% of OLT recipients, both early (within 12 weeks) and later,\(^{[12–13]}\) and endotherapy used to be the first-line treatment.\(^{[16]}\) In a previous study, the AS resolution rate was >60% for balloon dilation with subsequent PBS insertion.\(^{[17]}\) However, this must be repeated at 3-month intervals for at least 1 year. Therefore, FCEM placement has attracted increasing attention; only 2 procedures are required: stent placement and removal. A systematic review published in 2013 found that metal stents show promise;\(^{[17]}\) since then, FCEMs have increasingly been used to treat AS.\(^{[18–20]}\) Today, an FCEM is an established alternative to PBS. Temporary FCEM placement (usually for 6 months) in patients with post-OLT AS affords initial resolution rates of 87.5% to 100% and recurrence rates of

### Table 2

| Total, n = 43 | Migration group, n = 21 | Nonmigration group, n = 22 |
|--------------|-------------------|----------------------|
| **Age (yr, mean)** | 52.0 | 51.2 | 52.7 |
| **AS length (cm, mean ± SD)** | 0.70 ± 0.55 | 0.59 ± 0.34 | 0.81 ± 0.68 |
| **Diameter of the donor bile duct (cm, mean ± SD)** | 0.99 ± 0.27 | 1.00 ± 0.25 | 0.98 ± 0.29 |
| **Diameter of the recipient bile duct (cm, mean ± SD)** | 0.85 ± 0.20 | 0.85 ± 0.18 | 0.85 ± 0.21 |
| **Time from the day of OLT to the day of FCEM placement (mo)** | 3.86 ± 3.93 | 4.19 ± 4.25 | 3.54 ± 3.68 |
| **Albumin (35–55 g/L)** | 39.06 ± 4.03 | 38.58 ± 3.65 | 39.52 ± 4.40 |
| **ALT (5–40 U/L)** | 50.19 ± 53.40 | 66.52 ± 68.19 | 34.59 ± 27.46 |
| **AST (8–40 U/L)** | 40.72 ± 30.90 | 52.48 ± 35.66 | 29.50 ± 20.71 |
| **GGT (11–50 U/L)** | 153.70 ± 174.01 | 167.38 ± 189.32 | 140.64 ± 161.42 |
| **AKP (11–150 U/L)** | 156.35 ± 99.28 | 149.76 ± 88.71 | 162.24 ± 110.14 |
| **TB (0–21 μmol/L)** | 18.84 ± 20.07 | 21.48 ± 25.61 | 16.32 ± 12.94 |
| **DB (0–5 μmol/L)** | 13.49 ± 19.43 | 16.48 ± 25.28 | 10.63 ± 11.34 |

**AKP** = alkaline phosphatase, **ALT** = alanine aminotransferase, **AS** = anastomotic stricture, **AST** = aspartate aminotransferase, **DB** = direct bilirubin, **FCEM** = fully-covered self-expandable metallic stent, **GGT** = γ-glutamyl transpeptidase, **OLT** = orthotopic liver transplantation, **TB** = total bilirubin.

### Table 3

| Variables | Univariate | Multivariate |
|-----------|------------|--------------|
|           | P value    | P value | HR | 95% CI |
| AST       | < .05      | .028     | 0.968 | 0.940–0.996 |
| ALT       | > .05      | .807     | / | / |
| Sphincterotomy status | < .05 | .187 | / | / |
| FCEM brand | > .05 | .074 | / | / |
| Age       | > .05      | .302     | / | / |
| Gender    | > .05      | .831     | / | / |
| ABO incompatibility | > .05 | .658 | / | / |
| Diabetes and/or hypertension status | > .05 | .857 | / | / |
| ALP length | > .05 | .257 | / | / |
| Diameter of the donor bile duct | > .05 | .856 | / | / |
| Diameter of the recipient bile duct | > .05 | .875 | / | / |
| Size mismatch between donor and recipient bile duct > 2 mm | > .05 | .621 | / | / |
| Nasobiliary drainage or PBS before FCEM placement | > .05 | .161 | / | / |
| Time from the day of OLT to the day of FCEM placement | > .05 | .362 | / | / |
| Length of FCEM | > .05 | .624 | / | / |
| Cholangiocarcinoma of OLT | > .05 | .124 | / | / |
| Albumin   | > .05      | .753     | / | / |
| GGT       | > .05      | .398     | / | / |
| AKP       | > .05      | .139     | / | / |
| TB        | > .05      | .975     | / | / |
| DB        | > .05      | .942     | / | / |

95% CI = 95% confidence interval, **AKP** = alkaline phosphatase, **ALT** = alanine aminotransferase, **AS** = anastomotic stricture, **AST** = aspartate aminotransferase, **DB** = direct bilirubin, **FCEM** = fully-covered self-expandable metallic stent, **GGT** = γ-glutamyl transpeptidase, **HR** = hazard ratio, **OLT** = orthotopic liver transplantation, **PBS** = plastic biliary stent, **TB** = total bilirubin.
4.5% to 7.4%.\textsuperscript{[12]} However, stent migration remains a major concern. Zairi et al\textsuperscript{[10]} reported migration in 0% to 41% of cases, whereas Devière et al\textsuperscript{[21]} reported migration rates of up to 75% at 6 months.

At our center, the proximal ends of the FCEMs all passed over the narrow segments of the anastomotic stoma (above the AS by 1–1.5 cm) and were placed by professional endoscopists. The auto-migration rate was still relatively high, attaining 48.8% at 6 months. It could not be simply attributed to the changes in anatomical structure or the destruction of nerve fibers controlling biliary tract contraction. For a potential explanation, this retrospective study was performed to determine the risk factors.

AST and ALT have been regarded as classical markers of liver injury, including a wide range of etiologies from viral hepatitis to novel coronavirus disease 2019.\textsuperscript{[22,23]} Meanwhile, cholangitis secondary to biliary stricture can also cause serum elevation of AST and ALT. Furthermore, liver transplant specialists have disclosed that AST and ALT are very sensitive tests in post-OLT patients with biliary stricture and graft rejection\textsuperscript{[24,25]}; serum levels of AST and ALT are at least 2-fold higher in the graft rejection group than in the biliary stricture group (222 vs 101.6 U/L, 337.4 vs 158.6 U/L, respectively).\textsuperscript{[26]} In 2009, Traina et al\textsuperscript{[8]} reported that the average value of ALT in 16 patients with AS after liver transplantation was 149 U/L. In 2020, Warner et al\textsuperscript{[27]} reported that the average value of AST before ERCP was 101 U/L in 54 patients with AS after liver transplantation. In the present study, the serum levels of AST and ALT seemed relatively lower at 40.72, 52.48, and 29.50 U/L, 50.19, 66.52, and 34.59 U/L, respectively, in total patients, in the migration group, and in the nonmigration group. This may be partly related to different regions, countries, and races. Interestingly, we found that serum levels of AST and ALT were significantly higher in the migration group than that in the nonmigration group, and that an elevated serum AST level was a potential risk factor for FCEM migration. So far, this is the first time to disclaim the relationship between AST and FCEM displacement, and the internal mechanism is not yet clear. It is also unclear why ALT, the other indicator of hepatocyte injury, is not a risk factor for FCEM displacement, which is worthy of further study.

A high preoperative serum level of bilirubin is an independent risk factor for biliary complications (including AS and bile leakage) post-OLT.\textsuperscript{[28]} and AKP and GGT have been considered as an early, noninvasive, and inexpensive markers for diagnosing AS.\textsuperscript{[29]} We postulated that FCEM migration was related to the narrow segments of the anastomotic stoma (above the AS by 1 cm) and were placed by professional endoscopists. The auto-migration rate was still relatively high, attaining 48.8% at 6 months. It could not be simply attributed to the changes in anatomical structure or the destruction of nerve fibers controlling biliary tract contraction. For a potential explanation, this retrospective study was performed to determine the risk factors.

In conclusion, stent migration remains the major drawback of FCEM use. Given that the number of OLT patients is increasing, and the incidence of AS is not decreasing, risk factors for FCEM migration must be urgently identified.

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References

[1] Starzl TE, Marchioro TL, Vonkaulla KN, Herrmann G, Brittain RS, Waddell WR. Homotransplantation of the liver in humans. Surg Gynecol Obstet 1963;117:639–76.
[2] Greif F, Bronsther OL, van Thiel DH, et al. The incidence, timing and management of biliary complications after orthotopic liver transplantation. Ann Surg 1994;219:40–5.
[3] Rossi G, Lucianetti A, Gridelli B, et al. Biliary tract complications in 224 orthotopic liver transplantations. Transplant Proc 1994;26:3626–8.
[4] Evans RA, Raby ND, O'Grady JG, et al. Biliary complications following orthotopic liver transplantation. Clin Radiol 1990;41:190–4.
[5] Arain MA, Attam R, Freeman ML. Advances in endoscopic management of biliary tract complications after liver transplantation. Liver Transpl 2013;19:482–98.
[6] de C, Visconti TA, Bernardo WM, Moura DTH, et al. Metal vs plastic stents to treat biliary stricture after liver transplantation: a systematic review and meta-analysis based on randomized trials. Endosc Int Open 2018;06:914–23.
[7] Kaffes A, Griffin S, Vaughan R, et al. A randomized trial of a fully covered self-expandable metallic stent versus plastic stents in anastomotic biliary strictures after liver transplantation. Therap Adv Gastroenterol 2014;7:64–71.
[8] Traina M, Tarantino I, Barresi I, et al. Efficacy and safety of fully covered self-expandable metallic stents in biliary complications after liver transplantation: a preliminary study. Liver Transpl 2009;15:1493–8.
[9] Tee HP, James MW, Kaffes AJ. Placement of removable metal biliary stent in post-orthotopic liver transplantation anastomotic stricture. World J Gastroenterol 2010;16:3597–600.

[10] Zeair S, Butkiewicz F, Butkiewicz J, Stasiuk R. Application of fully covered self-expandable metallic stents with and without antimigration waist versus repeated plastic biliary stent placement in management of anastomotic biliary strictures after orthotopic liver transplantation. Ann Transplant 2017;22:719–24.

[11] Facciorusso A, Rosca EC, Ashimi A, et al. Management of anastomotic biliary stricture after liver transplantation: metal versus plastic stent. Ann Gastroenterol 2018;31:728–34.

[12] Martins FP, Kahaleh M, Ferrari AP. Management of liver transplantation biliary stricture: results from a tertiary hospital. World J Gastrointest Endosc 2015;7:747–57.

[13] Atwal T, Pastrana M, Sandhu B. Post-liver transplant biliary complications. J Clin Exp Hepatol 2012;2:81–5.

[14] Welling T, Heidt D, Englesbe M, et al. Biliary complications following liver transplantation in the model for end-stage liver disease era: effect of donor, recipient, and technical factors. Liver Transpl 2008;14:73–80.

[15] Verdonk RC, Buis CI, van der Jagt EJ, et al. Nonanastomotic biliary strictures after liver transplantation, part 2: management, outcome, and risk factors for disease progression. Liver Transpl 2007;13:725–32.

[16] Williams ED, Draganov PV. Endoscopic management of biliary strictures after liver transplantation. World J Gastroenterol 2009;15:3725–33.

[17] Kao D, Zepe-da-Gomez S, Tandon P, Bain VG. Managing the post-liver transplantation anastomotic biliary stricture: multiple plastic versus metal stents: a systematic review. Gastrointest Endosc 2013;77:679–91.

[18] Tarantino I, Mangiavillano B, Di Mitri R, et al. Fully covered self-expandable metallic stents in benign biliary strictures: a multicenter study on efficacy and safety. Endoscopy 2012;44:923–7.

[19] Park DH, Lee SS, Lee TH, et al. Anchoring flap versus flared end, fully covered self-expandable metal stents to prevent migration in patients with benign biliary strictures: a multicenter, prospective, comparative pilot study (with videos). Gastrointest Endosc 2011;73:64–70.

[20] Poley JW, Cahen DL, Metselaar HJ, et al. A prospective group sequential study evaluating a new type of fully covered self-expandable metal stent for the treatment of benign biliary strictures (with video). Gastrointest Endosc 2012;75:783–9.

[21] Devière J, Nageshwar Reddy D, Puspoa A, et al. Successful management of benign biliary strictures with fully covered self-expanding metal stents. Gastroenterology 2014;147:385–95.

[22] Sookoian S, Pirola CJ. Liver enzymes, metabolomics and genome-wide association studies: from systems biology to the personalized medicine. World J Gastroenterol 2015;21:711–25.

[23] Bertolini A, van de Peppel IP, Bodewes FAJA, et al. Abnormal liver function tests in patients with COVID-19: relevance and potential pathogenesis. Hepatology 2020;72:1864–72.

[24] Zoepf T, Maldonado-Lopez EJ, Hilgard P, et al. Diagnosis of biliary strictures after liver transplantation: which is the best tool? World J Gastroenterol 2005;11:2943–8.

[25] Chiu KW, Chen YS, Villa VH, et al. Characterization of liver enzymes on living related liver transplantation patients with acute rejection. Hepatogastroenterology 2005;52:1825–7.

[26] Chiu KW, Lee KH, Lee KT, et al. Postoperative changes of liver enzymes can distinguish between biliary stricture and graft rejection after living donor liver transplantation: a longitudinal study. Medicine (Baltimore) 2017;96:40–6.

[27] Warner B, Harrison P, Farman M, et al. A unique type of fully covered metal stent for the management of post liver transplant biliary anastomotic strictures. BMC Gastroenterol 2020;20:329–34.

[28] Qian YB, Liu C, Lo C, Fan ST. Risk factors for biliary complications after liver transplantation. Arch Surg 2004;139:1101–5.

[29] Shastri YM, Hoepffner NM, Akoglu B, et al. Liver biochemistry profile, significance and endoscopic management of biliary tract complications post orthotopic liver transplantation. World J Gastroenterol 2007;13:2819–25.