Biliary self-expandable metallic stent combined with iodine-125 seeds in the treatment of malignant biliary obstruction (Bismuth type I or II)

Jie Chai1 · Kaicai Liu2 · Beibei Xu1 · Lijun Wang1 · Huafeng Yu1 · Weifu Lv1 · Dong Lu1

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Abstract
Background The purpose of this research was to evaluate the safety and efficacy of a self-expandable metallic stent (SEMS) combined with iodine-125 (125I) seeds in the treatment of Bismuth type I or II malignant biliary obstruction (MBO).
Methods The clinical data of 74 cases of MBO treated with percutaneous SEMS combined with 125I seeds (combination group) and 81 cases of MBO treated with SEMS implantation alone (control group) in our hospital from January 2015 to December 2019 were retrospectively analyzed. The short-term and long-term efficacy of the two groups were compared. Multivariate Cox regression analysis was used to analyze the factors affecting the surgical efficacy and survival rate.
Results The liver blood test results of both groups improved at one week and one month post-stent insertion. No significant difference was established in the short-term efficacy or complications between the two groups (P = NS). Improved stent patency was observed in the combined group, 9.01 ± 4.38 months versus 6.79 ± 3.13 months, respectively (P < 0.001). Improved survival was also noted in the combined group 12.08 ± 5.38 months and 9.10 ± 4.16 months, respectively (P < 0.001). Univariate and multivariate analyses showed that the type of biliary stent and liver metastasis were independent factors affecting survival.
Conclusion The implementation of SEMS combined with 125I seeds resulted in significantly longer stent patency and survival times than that of SEMS implantation alone, which is thus worthy of clinical promotion and application.

Keywords Self-expandable metallic stent · Malignant biliary obstruction · 125I seeds · Radioactive material · Tumor

Malignant biliary obstruction (MBO) is directly or indirectly caused by malignant tumors such as pancreatic cancer and cholangiocarcinoma, with insidious onset and poor prognosis [1, 2]. Tumor and malignant lymph node infiltration into the surrounding tissues and organs is common in this disorder, leading to a relatively low overall surgical resection rate of tumor lesions [3, 4]. Even after surgery, complications, such as liver failure, infection, and tumor recurrence, often occur. Nevertheless, since biliary drainage and stent placement can relieve the symptoms of biliary obstruction and improve the quality of life of patients, they have become a preferred palliative treatment [5, 6]. However, tumor tissue continues to grow after stent placement, which is likely to lead to stent obstruction, resulting in a poor long-term treatment effect. According to a previous report, the patency time of bare metal biliary tract stents is approximately 88.3 days [7]. A fully covered metal biliary stent can effectively inhibit tumor tissue growth through the mesh and prolong the median patency time to approximately 118 days after stent implantation; however, the drainage of bile and pancreatic fluid may be affected after stent implantation, related complications may occur, and the displacement rate of these stents is higher [8]. The combination of biliary stent implantation and radionuclide internal radiotherapy has been widely used in clinical practice, as these approaches can complement each other and compensate for each other's shortcomings. For example, the stent relieves the symptoms of biliary obstruction and attenuates patients'...
systemic conditions, while the radionuclide inhibits tumor growth, improving the long-term patency rate of the stent and prolonging the survival time. A number of domestic researchers have explored covering the biliary stent with a film coating of radionuclide particles to perform radionuclide internal radiation therapy on or around a biliary stent [9]. $^{125}$I seeds were directly bound to the biliary stent, or a plastic tube containing $^{125}$I seeds was pressed around the stent [4, 10, 11]. However, the dose of radionuclides cannot be adjusted according to the specific characteristics of the lesions in practice. Hence, the consistency of the radiation dose and its distribution throughout the lesion cannot be guaranteed; the displacement, shedding and leakage of radionuclides after operation are also hidden dangers.

In this study, a brachytherapy system consisting of a particle carrying $^{125}$I seeds and a self-expandable metallic stent (SEMS), developed by Nanjing MicroPort (Nanjing, China), combined with a specially designed treatment planning system (TPS), was used in patients with MBO. In this study, we aimed to explore the safety and effectiveness of SEMS combined with $^{125}$I seed implantation in the biliary tract. Furthermore, we intended to examine whether this combination can prolong the biliary opening time and overall survival time.

Materials and methods

Patients

The data of patients with MBO who underwent biliary stenting in the First Affiliated Hospital of China University of Science and Technology from January 2015 to December 2019 were retrospectively analyzed.

The inclusion criteria were as follows: (1) age 18–80 years; (2) clinical symptoms of biliary obstruction, such as jaundice; (3) malignant biliary obstruction confirmed by imaging, laboratory examination, tissue/cytology biopsy, or previous operation; (4) Bismuth–Corlette type I or II bile duct obstruction; (5) The Eastern Cooperative Oncology Group score within 0–3; and (6) inability or refusal to undergo surgery. The following exclusion criteria were applied: (1) benign biliary obstruction; (2) inability to expand the obstruction completely and inability of the stent conveyor to pass through the obstructed section; (3) complication with biliary perforation; (4) previous history of stent placement or biliary surgery; (5) contraindications of percutaneous transhepatic biliary drainage; and (6) uncontrollable infection. Finally, based on the different forms of biliary stents, the sample was divided into 81 patients receiving simple biliary stent treatment and 74 patients receiving internal irradiation with $^{125}$I particles. The study flow chart is presented in Fig. 1.

This study was approved by the Ethics Committee of our hospital (No. 2022-RE-297) and was conducted in compliance with the standards of the Declaration of Helsinki. Due to the retrospective nature of this study, the ethics committee waived the requirement for informed consent.

Device materials

A percutaneous transhepatic biliary drainage (PTCD) trocar (Cook Medical, Cook Medical, Bloomington, IN, USA) and a supersmooth guide wire and a 5-F Cobra contrast catheter (Cordis, New Brunswick, New Jersey, USA) were used in our interventions. The biliary stent was provided by the Nanjing Institute of Minimally Invasive Research (Nanjing, China). A stent with a length of 6–10 cm and a diameter of 8–10 mm was utilized. The structure of the stent was combined with particles, forming a double-layer structure. A SEMS and a stent carrying $^{125}$I seeds (Chengdu Yunke Pharmaceutical Co., Ltd, Chengdu, China) were deployed to the target bile duct and assembled. The diameter of the high-purity titanium shell was 0.8 mm, and its length was 4.5 mm. It had a built-in 3-mm $^{125}$I silver rod with an activity of 0.3–6.0 mCi, a prescription dose of $^{125}$I seeds (CIAE-6711; China Institute of Atomic Energy, Beijing). Planning and calculation were based on the guidelines of a treatment planning system (FTT technology, Beijing, China). Before the stent was placed, $^{125}$I seeds were assembled into the capsule of the stent, which was then attached to the external surface of the stent.

Radiological intervention method

Imaging examination and preoperative evaluation

All patients underwent dual-phase CT enhancement and Magnetic Resonance Cholangiopancreatography (MRCP) scanning to determine the tumor focus range, biliary obstruction level, and the length of the stenotic segment and to establish the relationship between the tumor and its important surrounding vessels. Hence, we determined the length of the biliary tract particle scaffold, the location of implantation, and the number of $^{125}$I seeds.

Radiological intervention procedure

The steps described below were followed in the radiological intervention procedure.

(1) With the patient in the supine position, we determined the skin puncture point and punctured the dilated bile duct with a PTCD special puncture needle under fluoroscopy or B-ultrasound monitoring.
We injected the contrast medium to determine the length of the lesion and the degree of obstruction, and marked them. We then withdrew the catheter and replaced it with a 260-cm superstiff and superlong guide wire.

We chose an appropriate stent system for intrabiliary irradiation according to the length of the lesion. The particle segment of the particle carrying device was required to completely cover the lesion.

If necessary, a balloon of appropriate length was used to dilate the obstructed biliary tract, and then the seeds carrying the device were pushed to the lesion site along the superstiff guide wire. The proximal positioning method was applied to confirm the accurate positioning before release.

After releaser withdrawal, the common biliary stent was pushed to the biliary obstruction section along the superstiff guide wire so that it overlapped with the particle segment of the biliary particle device. The upper and lower edges of the internal irradiation stent system had to exceed the lesion by approximately 10 mm.

After the intervention, the external drainage tube was inserted, flushed with metronidazole 50 mL for three consecutive days, and clamped. The drainage tube was left in for one week to determine the patency of the stent, and then the drainage tube was removed.

Fig. 1 Flow diagram illustrating the treatment process
Postoperative treatment

After the intervention, all patients received ECG monitoring, oxygen inhalation, liver protection, as well as jaundice, hemostasis, anti-infection, and symptomatic treatment. We observed the color, quality, and quantity of the drained bile fluid. For patients with unobstructed biliary drainage and no infection, bleeding or other signs, PTCD was clamped 3–7 days post-intervention based on the bile drainage volume, color, and turbidity. If there was no obvious discomfort, the drainage tube was removed. One week after the intervention, a single-photon emission computed tomography (SPECT) scan was done to detect the radioactivity and the position of the $^{125}$I seed chain (Fig. 2A–F). Interventional treatment was then performed to continue the treatment of other lesions.

Evaluation method and follow‑up examinations

1) Short-term efficacy: The incidence of postoperative complications was observed, and liver function, renal function, and blood routine were reexamined one week and one month after radiological intervention to evaluate the recovery of liver function and the curative effect on jaundice regression

2) Long-term efficacy: The long-term efficacy (postoperative biliary tract opening status and postoperative survival time) was compared between the observation group and the control group

3) Influencing factors: To evaluate whether sex, age, etiology, liver function or obstruction site was an independent influencing factor of surgical efficacy, after the last return to the hospital for reexamination, telephone return visits were made once a month to collect data on the patient’s survival, clinical symptoms, recurrence of jaundice, and new complications. Three, 5, 7, 9, and 12 months after the intervention, computed tomography (CT) was redone in the hospital or outside the hospital to view the distribution of the biliary stent and $^{125}$I seeds and evaluate the opening of the biliary tract.

Statistical analysis

SPSS 22.0 statistical software (IBM, Armonk, NY, USA) was employed for statistical analysis. Continuous data conforming to a normal distribution are presented as mean ± SD and were compared using Student’s $T$-test. Continuous data that were not normally distributed are presented as median (interquartile range) and were compared using the Mann–Whitney $U$-test. The Kaplan–Meier method was

![Fig. 2](image)

Fig. 2 A 66-year-old man with cholangiocarcinoma. Preoperative MR scan showed intrahepatic bile duct dilatation (A), and DSA showed obstruction of the middle and upper segments of the common bile duct with intrahepatic bile duct dilatation (B). After implantation of the biliary stent combined with $^{125}$I seeds, the obstruction was relieved, and the contrast agent entered the intestinal cavity smoothly (C). Postoperative SPECT/CT showed that the gamma radiation range of iodine particles covered the lesions in the middle and upper common bile duct (D–F)
applied to analyze the stent patency time and survival time, and the log-rank test was used for comparison between groups. Multivariate Cox regression analysis was employed to analyze the factors affecting surgical efficacy and survival. All results were considered statistically significant at $P < 0.05$.

**Results**

**Radiological intervention results**

The success rate of radiological intervention procedure of all 155 patients was 100%. The baseline characteristics of the 81 patients receiving simple biliary stent treatment and the 74 patients receiving biliary stent with $^{125}$I seeds treatment groups were well similar (Table 1). The survival time of all patients was more than 30 days, and thus the treatment efficacy could be evaluated in all of them.

**Short-term efficacy**

The liver function of all 155 patients improved significantly at one and four weeks after the radiological intervention. The short-term effect of each treatment on malignant obstructive jaundice was good, and the jaundice obviously subsided compared with their preoperative condition, with a statistically significant difference ($P < 0.001$). No significant difference was found between the two groups in the short-term effect ($P > 0.05$; Table 2).

**Complications**

Complications were assessed according to the Common Terminology Criteria for Adverse Events (CTCAE 4.02). The incidence of complications in the combined group was 18.92%, including eight cases of abdominal pain, one of biliary bleeding, two of pancreatitis, one of cholangitis, and two of sepsis. The incidence of complications in the control group was 11.11%, including six cases of abdominal pain, two of pancreatitis, and one of sepsis. All complications improved after symptomatic treatment. No biliary stent or $^{125}$I seed strip displacement was observed post-procedure. No significant difference was present in the incidence of complications between the two groups (Table 3).

**Stent patency time**

After a follow-up period of 3, 5, 7, 9, and 12 months or upon return to the hospital for reexamination, the patency of the biliary tract was examined. The overall opening times of the biliary stents in the two groups were $9.01 \pm 4.38$ months and

| Variables                  | Combination group ($n=74$) | Control group ($n=81$) | $x^2/t$ | $P$-value |
|---------------------------|---------------------------|------------------------|---------|-----------|
| Age (years)               |                           |                        | 1.031   | 0.309     |
| $\geq 50$                 | 67                        | 69                     |         |           |
| $< 50$                    | 7                         | 12                     |         |           |
| Sex                       |                           |                        | 3.759   | 0.053     |
| Male                      | 38                        | 54                     |         |           |
| Female                    | 36                        | 27                     |         |           |
| Bismuth–Corlette          |                           |                        | 0.321   | 0.571     |
| Type I                    | 35                        | 42                     |         |           |
| Type II                   | 39                        | 39                     |         |           |
| KFS (score)               |                           |                        | 3.281   | 0.07      |
| $\geq 70$                 | 62                        | 58                     |         |           |
| $< 70$                    | 12                        | 23                     |         |           |
| Laboratory test           |                           |                        |         |           |
| TBIL ($\mu$mol/L)         | 221.84 ± 110.93           | 214.48 ± 148.83        | 0.274   | 0.785     |
| ALT ($\mu$L)              | 106.99 ± 81.02            | 134.08 ± 126.89        | 1.228   | 0.222     |
| AST ($\mu$L)              | 113.85 ± 80.10            | 128.72 ± 96.01         | 0.842   | 0.402     |
| ALB ($\mu$mol/L)          | 33.95 ± 6.82              | 35.03 ± 5.53           | 0.928   | 0.355     |
| PT (s)                    | 11.95 ± 1.83              | 12.71 ± 1.99           | 1.796   | 0.051     |
| Intrahepatic metastasis   |                           |                        | 1.5     | 0.221     |
| Yes                       | 32                        | 43                     |         |           |
| No                        | 42                        | 38                     |         |           |

$PFS$ performance status, $TBIL$ total bilirubin, $ALT$ alanine aminotransferase, $AST$ aspartate aminotransferase, $ALB$ albumin, $PT$ prothrombin time
6.24 ± 0.48 months, respectively. Kaplan–Meier analysis was used to draw a survival curve (Fig. 3a), and the log-rank test was applied to compare the curves of the two groups. The results showed that the stent patency time of biliary stents loaded with $^{125}$I seeds was significantly longer than that of simple biliary stents ($P < 0.05$).

### Table 2 Laboratory Values before and after Stent Placement

| Laboratory test | Combination group ($n = 74$) | Control group ($n = 81$) | $P$-value |
|-----------------|-----------------------------|-------------------------|-----------|
| TBIL (μmol/L)   |                             |                         |           |
| Preoperative    | $214.48 ± 148.83$           | $221.84 ± 110.93$       | 0.785     |
| After 1 week    | $141.87 ± 92.47^a$          | $151.68 ± 93.95^a$      | 0.707     |
| After 1 month   | $64.40 ± 64.08^{a*}$        | $69.35 ± 63.55^{a*}$    | 0.782     |
| DBIL (μmol/L)   |                             |                         |           |
| Preoperative    | $164.86 ± 88.43$            | $178.65 ± 63.39$        | 0.428     |
| After 1 week    | $96.53 ± 85.74^a$           | $113.03 ± 93.35^a$      | 0.506     |
| After 1 month   | $35.36 ± 40.27^{a*}$        | $42.67 ± 38.55^{a*}$    | 0.381     |
| IBIL (μmol/L)   |                             |                         |           |
| Preoperative    | $58.33 ± 45.62$             | $50.68 ± 43.39$         | 0.693     |
| After 1 week    | $45.34 ± 25.38$             | $38.65 ± 24.57$         | 0.436     |
| After 1 month   | $29.04 ± 25.38^a$           | $26.38 ± 18.43^a$       | 0.212     |
| ALT (μ/L)       |                             |                         |           |
| Preoperative    | $106.99 ± 81.02$            | $134.08 ± 126.89$       | 0.222     |
| After 1 week    | $68.54 ± 48.61$             | $79.21 ± 55.27$         | 0.426     |
| After 1 month   | $32.36 ± 14.72^a$           | $42.65 ± 27.62^a$       | 0.182     |
| AST (μ/L)       |                             |                         |           |
| Preoperative    | $106.21 ± 84.45$            | $142.72 ± 145.70$       | 0.425     |
| After 1 week    | $61.43 ± 51.61^a$           | $81.21 ± 59.01$         | 0.354     |
| After 1 month   | $30.29 ± 13.94^a$           | $47.86 ± 29.78^a$       | 0.056     |
| TBA (μmol/L)    |                             |                         |           |
| Preoperative    | $56.44 ± 33.24$             | $66.71 ± 23.36$         | 0.454     |
| After 1 week    | $43.67 ± 34.40$             | $51.43 ± 33.02$         | 0.056     |
| After 1 month   | $27.33 ± 14.50$             | $30.01 ± 13.79^a$       | 0.454     |

* Represents $P < 0.05$ compared with preoperatively, * represents $P < 0.05$ compared with one week after surgery

### Table 3 Complications in the two groups

| Complication     | Combination group ($n = 74$) | Control group ($n = 81$) | $P$-value |
|------------------|------------------------------|--------------------------|-----------|
| Abdominal pain   | 8                            | 6                        | 0.460     |
| Bleeding         | 1                            | 0                        | 0.294     |
| Pancreatitis     | 2                            | 2                        | 0.927     |
| Cholangitis      | 1                            | 0                        | 0.294     |
| Septicemia       | 2                            | 1                        | 0.508     |

Survival and its influencing factors

The cumulative survival rates of the two groups of patients at 3, 6, and 12 months were 99%, 89%, and 68% (combined group) versus 96%, 79%, and 47% (control group), respectively. The survival curves of the two groups were drawn by the Kaplan–Meier method (Fig. 3b). The log-rank test showed that the average survival time of the combined group and control group was 12.08 ± 5.38 months and 9.10 ± 4.16 months, respectively. There was a significant difference in the survival time between the two groups ($\chi^2 = 10.576$, $P = 0.001$). Univariate analysis revealed that...
the type of biliary obstruction, intrahepatic metastasis, and stent type were significantly correlated with the survival. Multivariate Cox analysis showed that intrahepatic metastasis and stent type were independent prognostic factors that affected survival (Table 4).

**Discussion**

Most patients with obstructive jaundice caused by malignant tumors lose their opportunity for surgical treatment [12]. Biliary stent implantation and reopening of the occluded bile duct is the main current treatment method. Tumor progression and stent intimal hyperplasia are the most important reasons for the recurrence or deterioration of jaundice in patients [13, 14]. Therefore, to the discovery and development of methods for tumor growth control and delay of the hyperplasia of the bile duct intima are the critical for the prevention of stent blockage and for prolonging the survival time of patients. Previous clinical studies have used biliary stents combined with external radiotherapy [15], biliary stents combined with arterial intubation chemoembolization [16] and the installation of radiotherapy devices for biliary radiotherapy [17], as well as other methods. Due to the poor basic condition of patients, the sensitivity of the surrounding organs to radiotherapy, the limitation of the primary tumor type, and the cumbersome surgical operation, these methods cannot be widely used in clinical applications. SEMS combined with 125I seed implantation and intracavitary irradiation has been applied to treat malignant biliary obstruction [18, 19], and certain clinical effects have been achieved.

125I seeds are elicit low-dose-rate microradiation of γ-rays. Because of their short range of radiation, low penetration, and maximum tumor-killing effect without damaging the surrounding normal tissues, 125I seeds have been used in radiotherapy. They have been applied in the clinical treatment of prostate, rectal, nasopharyngeal, and liver cancers, and other malignant tumors with good results [20–22]. Based on the advantages of 125I seeds, we explored the difference between the clinical efficacy of SEMS combined

*Table 4* Univariate and multivariate analyses of prognostic factors for survival

| Variable                         | Univariate analysis | Multivariate analysis |
|----------------------------------|---------------------|-----------------------|
|                                 | HR (95% CI)         | P-value               | HR (95% CI)         | P-value |
| Sex (M/F)                        | 0.915 (0.496–1.427) | 0.467                 |                     |         |
| Age (years) (≥ 50/< 50)          | 0.824 (0.475–1.543) | 0.147                 |                     |         |
| Bismuth type(I/II)               | 2.154 (1.245–3.517) | 0.008                 | 2.067 (1.159–4.282) | 0.074   |
| KPS score (≥ 70/< 70)            | 0.516 (0.278–1.162) | 0.143                 |                     |         |
| Total bilirubin level (≥ 200/< 200) (μmol/L) | 1.017 (0.754–2.143) | 0.241                 |                     |         |
| Intrahepatic metastasis (Y/N)    | 0.014 (0.015–0.212) | <0.001                | 0.021 (0.004–0.131) | <0.001  |
| Iodine-125 seeds (with/without)  | 3.287 (2.112–7.925) | <0.001                | 4.923 (2.435–8.568) | <0.001  |

Fig. 3  a Kaplan Meier survival curves for comparison of stent patency time between combined group and control group (P = 0.001). b Kaplan–Meier survival curves for comparison of OS between combined group and control group (P < 0.001)
with $^{125}$I seeds and SEMS alone in the treatment of MBO. In this study, $^{125}$I seeds were initially placed in a carrier device and fixed on the bile duct wall through the support of a biliary stent, which effectively eliminated the difficulty of direct puncture and implantation of $^{125}$I seeds for the treatment of malignant tumors growing along the bile duct. Compared with simple biliary stent implantation, the combination of a biliary stent and $^{125}$I seed implantation did not cause obstruction of bile drainage and ensured the patency of the biliary tract. Continuous radiation can effectively inhibit and kill tumor cells and reduce the proliferation of biliary intima [23, 24]. This treatment had an obvious curative effect in delaying the recurrence of obstructive jaundice. In this study, the bilirubin level was significantly improved at one week and one month after the biliary stent implantation in each group ($P < 0.001$). The two methods had good short-term curative effects in the treatment of MBO, with an obvious beneficial effect on jaundice, but the difference between the two groups was not statistically significant ($P > 0.05$). Although no significant difference was found between the two in short-term jaundice reduction, the recurrence time of jaundice in the combined group was significantly longer than that in the control group (9.01 months vs. 6.79 months, $P < 0.001$). This result is comparable to those of previous studies [25, 26]. In the present investigation, we also found that between-group differences in the incidence of jaundice recurrence started to occur five months post-biliary stent implantation. The main reason was that the combination method effectively killed the tumor cells in the bile duct wall or inhibited their growth, and then suppressed the intimal hyperplasia around the biliary stent, thereby delaying the recurrence of obstructive jaundice. In addition to delaying the recurrence of jaundice, the application of a combination of a biliary stent and brachytherapy can also prolong the survival time of patients. Although Isayama et al. [27] reported no differences in the cumulative survival rate of the combined implementation of a biliary stent and internal radiotherapy from that of R1 resection, the median survival time of the stent combined with internal radiotherapy group was significantly longer than that of the stent-only group. Our present results also showed that the median survival time of the combined group was significantly longer than that of the control group (12.08 months vs. 9.10 months, $P < 0.001$).

In addition, existing evidence has shown that the incidence of early complications of percutaneous biliary stent implantation ranges from 5.7 to 28%, the mortality rate related to the radiological intervention from 0 to 4%, and the mortality rate one month after the intervention from 9 to 15% [28]. Most of the complications can be resolved by conservative medical treatment, and the occurrence of death one month after the intervention is generally related to some of the original underlying diseases of the patient [28, 29]. The results of this study revealed that the early complication rates of the two groups of patients were 18.92% and 11.11%, both of which improved after conservative medical treatment; the surgery-related mortality rate was 0%. Previous research has shown that biliary drainage brings a risk of biliary tract infection and puncture tumor implantation and metastasis, and thus percutaneous biliary drainage and stent implantation should be done with cautious [29, 30]. In this study, we did not observe the occurrence of tumor implantation or metastasis in the puncture tract, which was due to the recent improvements of interventional treatment technology and equipment. Therefore, percutaneous biliary stent combined with $^{125}$I seed implantation is a relatively safe and feasible palliative treatment.

Some limitations of this study are to be acknowledged: it was retrospective, and the sample size was small. Therefore, prospective multicenter and larger randomized controlled studies are needed to confirm our results.

In conclusion, percutaneous liver puncture biliary stent placement combined with $^{125}$I seed implantation is safe, effective, and feasible for patients with unresectable Bismuth type I or II malignant biliary obstruction. This treatment scheme can extend the patency time of the stent as well as the survival time of patients.

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**Declarations**

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**References**

1. Fernandez Y, Viesca M, Arvanitakis M (2019) Early diagnosis and management of malignant distal biliary obstruction: a review on current recommendations and guidelines. Clin Exp Gastroenterol 12:415–432
2. Moole H, Bechtold M, Puli SR (2016) Efficacy of preoperative biliary drainage in malignant obstructive jaundice: a meta-analysis and systematic review. World J Surg Oncol 14(1):182
3. Boulay BR, Birg A (2016) Malignant biliary obstruction: from palliation to treatment. World J Gastrointest Oncol 8(6):498–508
4. Zhou C, Li H, Huang Q et al (2020) Biliary self-expandable metallic stent combined with iodine-125 seeds strand in the treatment of hilar malignant biliary obstruction. J Int Med Res 48(4):30060519887843
5. Dumonceau JM, Tringali A, Papanikolaou IS et al (2018) Endoscopic biliary stenting: indications, choice of stents, and results.
European Society of Gastrointestinal Endoscopy (ESGE) Clinical Guideline—Updated October 2017. Endoscopy 50(9):910–930
6. Mukai S, Itoi T, Baron TH et al (2017) Indications and techniques of biliary drainage for acute cholangitis in updated Tokyo Guidelines 2018. J Hepatobiliary Pancreat Sci 24(10):537–549
7. Hasimu A, Gu JP, Ji WZ et al (2017) Comparative study of percutaneous transhepatic biliary stent placement with or without iodine-125 seeds for treating patients with malignant biliary obstruction. J Vasc Inter Radiol 28(4):583–593
8. Kim JY, Ko GB, Lee TH et al (2017) Partially covered metal stents may not prolong stent patency compared to uncovered stents in unresectable malignant distal biliary obstruction. Gut Liver 11(3):440–446
9. Won JH, Lee JD, Wang HJ et al (2005) Effects of a holmium-166 incorporated covered stent placement in normal canine common bile ducts. J Vasc Inter Radiol 16(5):705–711
10. Zhou WZ, Fu YM, Yang ZQ et al (2019) Study of percutaneous stent placement with iodine-125 seed strand for malignant biliary obstruction. Cardiovasc Inter Radiol 42(2):268–275
11. Li S, Li B, Li L et al (2020) The efficacy of the combination of percutaneous transhepatic biliary drainage and 125I stranded seeds for malignant bile duct obstruction treatment. J Contemp Brachyther 12(3):225–232
12. Song S, Jin H, Cheng Q et al (2022) Local palliative therapies for unresectable malignant biliary obstruction: radiofrequency ablation combined with stent or biliary stent alone? An updated meta-analysis of nineteen trials. Surg Endosc 36(8):5559–5570
13. Almadi MA, Barkun A, Martel M (2017) Plastic vs. self-expandable metal stents for palliation in malignant biliary obstruction: a series of meta-analyses. Am J Gastroenterol 112(2):260–273
14. Acu B, Kurtulus OE (2018) Feasibility and safety of percutaneous transhepatic endobiliary radiofrequency ablation as an adjunct to biliary stenting in malignant biliary obstruction. Diagn Interv Imaging 99(4):237–245
15. Takamura A, Saito H, Kamada T et al (2003) Intraluminal low-dose-rate 192Ir brachytherapy combined with external beam radiotherapy and biliary stenting for unresectable extrahepatic bile duct carcinoma. Int J Radiat Oncol Biol Phys 57(5):1357–1365
16. Cao G, Cao H, Liu J et al (2013) One-channel double stent implantation for hilar biliary obstructions. Exp Ther Med 5(4):1179–1183
17. Xu X, Li J, Wu J et al (2018) A systematic review and meta-analysis of intraluminal brachytherapy versus stent alone in the treatment of malignant obstructive jaundice. Cardiovasc Inter Radiol 41(2):206–217
18. Pang Q, Zhou L, Hu XS et al (2019) Biliary stenting alone versus biliary stenting combined with 125I particles intracavitary irradiation for the treatment of advanced cholangiocarcinoma. Sci Rep 9(1):11348
19. Wang T, Liu S, Zheng YB et al (2017) Clinical study on using 125I seeds articles combined with biliary stent implantation in the treatment of malignant obstructive jaundice. Anticancer Res 37(8):4649–4653
20. Lu J, Guo JH, Zhu HD et al (2017) Safety and efficacy of irradiation stent placement for malignant portal vein thrombus combined with transarterial chemoembolization for hepatocellular carcinoma: a single-center experience. J Vasc Interv Radiol 28(6):796–794.e3
21. Huo X, Wang H, Yang J et al (2016) Effectiveness and safety of CT-guided 125I seed brachytherapy for postoperative locoregional recurrence in patients with non-small cell lung cancer. Brachytherapy 15(3):370–380
22. An R, Zhang H, Yu J et al (2021) Self-expandable metallic stent with 125I seed strand in malignant biliary obstruction; a self-made delivery system and novel implantation method. Ann Transl Med 9(24):1774
23. Wu JZ, Li CL, Shi HB et al (2022) Hepatic arterial infusion chemotherapy following simultaneous metallic stent placement and iodine-125 seed strands for advanced cholangiocarcinoma causing malignant obstructive jaundice: a propensity score matching study. Jpn J Radiol 40(4):396–403
24. Zhou X, Zhang W, Dou M et al (2022) 125I seeds inhibit proliferation and promote apoptosis in cholangiocarcinoma cells by regulating the AGR2-mediated p38 MAPK pathway. Cancer Lett 524:29–41
25. Lu J, Guo JH, Zhu HD et al (2017) Palliative treatment with radiation-emitting metallic stents in unresectable Bismuth type III or IV hilar cholangiocarcinoma. ESMO Open 2(4):e000242
26. Zhu HD, Guo JH, Huang M et al (2018) Irradiation stents vs. conventional metal stents for unresectable malignant biliary obstruction: a multicenter trial. J Hepatol 68(5):970–977
27. Isayama H, Tsujino T, Nakai Y et al (2012) Clinical benefit of radiation therapy and metallic stenting for unresectable hilar cholangiocarcinoma. World J Gastroenterol 18(19):2364–2370
28. Inal M, Akgül E, Aksungur E et al (2003) Percutaneous self-expandable uncovered metallic stents in malignant biliary obstruction. Complications, follow-up and reintervention in 154 patients. Acta Radiol 44(2):139–146
29. Ngu W, Jones M, Neal CP et al (2013) Preoperative biliary drainage for distal biliary obstruction and post-operative infectious complications. ANZ J Surg 83(4):280–286
30. Wang HW, Li XJ, Li SJ et al (2021) Biliary stent combined with iodine-125 seed strand implantation in malignant obstructive jaundice. World J Clin Cases 9(4):801–811

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