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Radioembolization for Primary and Metastatic Tumors of the Liver

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Related Policies (if applicable)
None

Disclaimer

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Coverage

Primary Hepatocellular Carcinoma
Radioembolization **may be considered medically necessary** to treat primary hepatocellular carcinoma that is unresectable and limited to the liver (see Policy Guidelines section).

Radioembolization **may be considered medically necessary** in primary hepatocellular carcinoma as a bridge to liver transplantation.

Primary Intrahepatic Cholangiocarcinoma
Radioembolization **may be considered medically necessary** to treat primary intrahepatic cholangiocarcinoma in individuals with unresectable tumors.

Metastases from Neuroendocrine Tumors
Radioembolization **may be considered medically necessary** to treat hepatic metastases from neuroendocrine tumors (carcinoid and noncarcinoid) with diffuse and symptomatic disease when systemic therapy has failed to control symptoms.

Unresectable Hepatic Metastases
Radioembolization **may be considered medically necessary** to treat unresectable hepatic metastases from colorectal carcinoma, melanoma (ocular or cutaneous), or breast cancer that are both progressive and diffuse, in individuals with liver-dominant disease who are refractory to chemotherapy or are not candidates for chemotherapy or other systemic therapies.

Other Indications
Radioembolization **is considered experimental, investigational and/or unproven** for all other hepatic metastases except as noted above.

Radioembolization **is considered experimental, investigational and/or unproven** for all other indications not described above.

Policy Guidelines

In general, radioembolization is used for unresectable hepatocellular carcinoma that is greater than 3 cm.

There is little information on the safety or efficacy of repeated radioembolization treatments or on the number of treatments that should be administered.

Radioembolization should be reserved for individuals with adequate functional status (Eastern Cooperative Oncology Group Performance Status 0 to 2), adequate liver function and reserve, Child-Pugh class A or B, and liver-dominant metastases.

Symptomatic disease from metastatic neuroendocrine tumors refers to symptoms related to excess hormone production.

Description

Radioembolization (RE), also referred to as selective internal radiotherapy, delivers small beads (microspheres) impregnated with yttrium 90 intra-arterially via the hepatic artery. The microspheres, which become permanently embedded, are delivered to tumors preferentially because the hepatic circulation is uniquely organized, whereby tumors greater than 0.5 cm rely on the hepatic artery for blood supply while the normal liver is primarily perfused via the portal vein. Radioembolization has been proposed as a therapy for multiple types of primary and metastatic liver tumors.

Treatments for Hepatic and Neuroendocrine Tumors
The use of external-beam radiotherapy and the application of more advanced radiotherapy approaches (e.g., intensity-modulated radiotherapy) may be of limited use in patients with

multiple diffuse lesions due to the low tolerance of the normal liver to radiation compared with the higher doses of radiation needed to kill the tumor.

Various nonsurgical ablative techniques have been investigated that seek to cure or palliate unresectable hepatic tumors by improving locoregional control. These techniques rely on extreme temperature changes (cryosurgery or radiofrequency ablation), particle and wave physics (microwave or laser ablation), or arterial embolization therapy including chemoembolization, bland embolization, or radioembolization.

Radioembolization

Radioembolization (referred to as selective internal radiotherapy in older literature) delivers small beads (microspheres) impregnated with yttrium-90 (Y90) intra-arterially via the hepatic artery. The microspheres, which become permanently embedded, are delivered to tumors preferentially because the hepatic circulation is uniquely organized, whereby tumors greater than 0.5 cm rely on the hepatic artery for blood supply while the normal liver is primarily perfused via the portal vein. Y90 is a pure beta-emitter with a relatively limited effective range and a short half-life that helps focus the radiation and minimize its spread. Candidates for radioembolization are initially examined by hepatic angiogram to identify and map the hepatic arterial system. At that time, a mixture of technetium 99-labeled albumin particles is delivered via the hepatic artery to simulate microspheres. Single-photon emission computed tomography is used to detect possible shunting of the albumin particles into the gastrointestinal or pulmonary vasculature.

Currently, 2 commercial forms of Y90 microspheres are available: a glass sphere (TheraSphere) and a resin sphere (SIR-Spheres). Noncommercial forms are mostly used outside the U.S. While the commercial products use the same radioisotope (Y90) and have the same target dose (100 gray), they differ in microsphere size profile, base material (i.e., resin vs. glass), and size of commercially available doses. The physical characteristics of the active and inactive ingredients affect the flow of microspheres during injection, their retention at the tumor site, spread outside the therapeutic target region, and dosimetry calculations. The U.S. Food and Drug Administration (FDA) granted premarket approval of SIR-Spheres for use in combination with 5-floxuridine chemotherapy by hepatic arterial infusion to treat unresectable hepatic metastases from colorectal cancer. In contrast, TheraSphere's glass sphere was approved under a humanitarian device exemption for use as monotherapy to treat unresectable hepatocellular carcinoma. In 2007, this humanitarian device exemption was expanded to include patients with hepatocellular carcinoma who have partial or branch portal vein thrombosis. For these reasons, results obtained with a product do not necessarily apply to another commercial (or non-commercial) products (see Regulatory Status section).

Regulatory Status

Currently, 2 forms of Y90 microspheres have been approved by the FDA.

In 1999, TheraSphere® (Boston Scientific; previously manufactured by Nordion, under license by BTG International), a glass sphere system, was approved by the FDA through the humanitarian

drug exemption process for radiotherapy or as a neoadjuvant treatment to surgery or transplantation in patients with unresectable hepatocellular carcinoma who can have placement of appropriately positioned hepatic arterial catheters (H980006).

On March 17, 2021, TheraSphere received approval through the premarket approval process for use as selective internal radiation therapy (SIRT) for local tumor control of solitary tumors (1 to 8 cm in diameter), in patients with unresectable hepatocellular carcinoma, Child-Pugh Score A cirrhosis, well-compensated liver function, no macrovascular invasion, and good performance status (P200029).

In 2002, SIR-Spheres® (Sirtex Medical), a resin sphere system, was approved by the FDA through the premarket approval process for the treatment of inoperable colorectal cancer metastatic to the liver (P990065).

FDA product code: NAW.

Rationale

Medical policies assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life, and ability to function including benefits and harms. Every clinical condition has specific outcomes that are important to patients and managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of technology, 2 domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent 1 or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

Radioembolization or Radioembolization Plus Liver Transplant for Unresectable Hepatocellular Carcinoma

Clinical Context and Therapy Purpose

The purpose of radioembolization (RE) or RE plus liver transplant in individuals who have unresectable hepatocellular carcinoma (HCC) is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

Populations
The relevant population of interest is individuals with unresectable HCC who may or may not need a liver transplant. Most patients with HCC present with unresectable disease and treatment options are limited secondary to the chemoresistance of HCC and the intolerance of normal liver parenchyma to tumoricidal radiation doses.

Interventions
The treatment being considered is RE with or without a liver transplant. RE may also be referred to as selective internal radiation therapy (SIRT) or transarterial radioembolization (TARE).

Comparators
The following are comparators to RE in the treatment of patients with unresectable HCC: standard of care, often palliative. Results of 2 RCTs have shown a survival benefit for transarterial chemoembolization (TACE) therapy compared with supportive care in patients with unresectable HCC. (1, 2) One study randomized patients to TACE, transarterial embolization (TAE), or supportive care. One-year survival rates for TACE, TAE, and supportive care were 82%, 75%, and 63%, respectively; 2-year survival rates were 63%, 50%, and 27%, respectively. Targeted therapies have been investigated for HCC. For example, sorafenib was associated with improved overall survival (OS) in a randomized phase 3 trial evaluating 602 patients. (3)

Outcomes
The general outcomes of interest are OS, functional outcomes, quality of life, and treatment-related morbidity (Table 1).

Table 1. Outcomes of Interest for Individuals with Unresectable Hepatocellular Carcinoma

Outcomes	Details
Treatment-related morbidity	Outcomes of interest include complete remission, partial response, PFS, OS, and stable disease [Timing: ≥3 months up to 5 years]

OS: overall survival; PFS: progression-free survival.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs.
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.

- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Within each category of study design, larger sample size studies and longer duration studies were preferred.
- Studies with duplicative or overlapping populations were excluded.

Radioembolization for Unresectable Hepatocellular Carcinoma

Systematic Reviews

Various meta-analyses have been performed to compare the effects of TACE, drug-eluting bead (DEB) plus TACE (DEB-TACE), and RE in patients with unresectable HCC, each of which performed slightly different analyses (e.g., pairwise vs. indirect comparisons and assessment of different outcomes or comparator groups). The results of these meta-analyses are summarized below.

Lu et al. (2025) performed a meta-analysis that compared outcomes of TACE and RE in patients with inoperable HCC. (4) The 8 included studies (7 retrospective, 1 non-randomized prospective) had a total of 1384 patients. At 1 year, OS was significantly higher with RE than with TACE (56.9% vs. 45.7%; p=.02), but there was no difference between groups in OS at 3 years and 5 years. The RE group had a lower incidence of fever (odds ratio, 0.11; 95% confidence interval [CI], 0.02 to 0.53; p=.006) and abdominal pain (odds ratio, 0.11; 95% CI, 0.02 to 0.70; p=.02) compared to TACE.

Pollock et al. (2021) conducted a systematic review and network meta-analysis of first-line treatments for unresectable HCC in TACE-ineligible patients. (5) Two RCTs comparing sorafenib to resin microspheres were analyzed, finding no significant differences in OS (hazard ratio [HR], 0.92; 95% CI, 0.79 to 1.08).

Venerito et al. (2020) performed a meta-analysis to assess the noninferiority of RE as monotherapy or followed by sorafenib versus sorafenib monotherapy on OS. (6) A noninferiority margin of 1.08 in terms of HR was prespecified. Three RCTs were included (N=1243), and meta-analysis demonstrated that RE with or without sorafenib was noninferior to sorafenib monotherapy in OS (median, 10.2 and 9.2 months; HR, 0.91; 95% CI, 0.78 to 1.05 months). Treatment-related severe adverse events were reported in 28.9% versus 43.3% of patients treated with RE as monotherapy or followed by sorafenib versus sorafenib monotherapy, respectively (p<.01).

Yang et al. (2020) conducted a meta-analysis of RCTs to compare the effects of DEB-TACE, TACE, and RE on the primary outcome of OS. (7) Compared with TACE, RE was associated with a similar 1-year OS (relative risk [RR], 0.91; 95% CI, 0.79 to 1.05), but a better OS than TACE at 2 years (RR, 0.87; 95% CI, 0.80 to 0.95) and 3 years (RR, 0.90; 95% CI, 0.85 to 0.96). The OS was not significantly different between RE and DEB-TACE at 1 year (RR, 0.83; 95% CI, 0.68 to 1.02), but DEB-TACE was associated with better OS at 2 years than RE (RR, 0.40; 95% CI, 0.19 to 0.84). However, pooled HRs indicated that RE was superior to TACE in OS (HR, 0.84; 95% CI, 0.70 to 1.00) and that DEB-TACE was superior to RE in OS (HR, 0.59; 95% CI, 0.38 to 0.91).

Tao et al. (2017) reported on a network meta-analysis comparatively evaluating 9 minimally invasive surgeries for the treatment of unresectable HCC. (3) The interventions included were TACE, TACE plus sorafenib, sorafenib, TACE plus high-intensity focused ultrasound, TACE plus percutaneous ethanol injection, DEB-TACE, yttrium-90 (Y90) RE, TACE plus external-beam radiation therapy (EBRT), and ethanol ablation. The network meta-analysis included 17 studies with 2669 patients and 4 studies with 230 patients including Y90 RE. In a pairwise meta-analysis, patients treated with Y90 RE were more likely to achieve complete remission than those who received TACE (odds ratio [OR], 4.5; 95% CI, 1.3 to 15.1). However, in the network meta-analysis, there was no significant difference between the corresponding 8 treatments and TACE with respect to complete remission, partial response, stable disease, and objective response rate. The treatments were ranked for several outcomes using surface under the cumulative ranking curves. TACE plus EBRT had the highest surface under the cumulative ranking curves in complete remission (77%), partial response (89%), progressive disease (95%), and objective response rate (81%).

Ludwig et al. (2017) conducted an indirect meta-analysis of studies that compared DEB-TACE with Y90 RE for HCC. (8) Fourteen studies (N=2065) comparing DEB-TACE or Y90 RE with conventional TACE for primary HCC treatment were included. The pooled estimate of median survival was 23 months for DEB-TACE and 15 months for RE. The estimated 1-year survival was significantly higher for DEB-TACE (79%) than for RE (55%; OR, 0.57; 95% CI, 0.36 to 0.92; p=.02). Survival did not differ statistically significantly at 2 or 3 years but did favor DEB-TACE. At 2 years, survival was 61% for DEB-TACE and 34% for RE (OR, 0.65; 95% CI, 0.29 to 1.44; p=.29), and at 3 years survival was 56% and 21% (OR, 0.71; 95% CI, 0.21 to 2.55; p=.62), respectively.

Two systematic reviews published in 2016 compared RE with TACE for the treatment of unresectable HCC. Lobo et al. (2016) selected 5 retrospective observational studies (N=533). (9) Survival at 1 year did not differ statistically between RE (42%) and TACE (46%; RR, 0.93; 95% CI, 0.81 to 1.08; p=.33). At 2 years, the survival rate was higher for RE (27% vs. 18%; RR, 1.36; 95% CI, 1.05 to 1.76; p=.02), but there was no statistically significant difference in survival rates at 3, 4, or 5 years. Postprocedural complications were also similar in the 2 groups. Facciorusso et al. (2016) included 10 studies (N=1557), 2 of which were RCTs. (10) The OR for survival was not statistically significant at 1 year (OR, 1.0; 95% CI, 0.8 to 1.3; p=.93) but favored RE in years 2 (OR, 1.4; 95% CI, 1.1 to 1.90; p=.01) and 3 (OR, 1.5; 95% CI, 1.0 to 2.1; p=.04).

Vente et al. (2009) conducted a meta-analysis evaluating tumor response and survival in patients who received a Y90 glass or resin microsphere RE for the treatment of primary HCC or metastases from colorectal cancer (CRC). (11) (Refer to the Unresectable Metastatic CRC section for the data from the meta-analysis as pertains to that disease.) Selected studies were from 1986 through 2008 and presented tumor response (measured by computed tomography) and data on median survival times. To allow comparability of results for tumor response, the category of "any response" was introduced and included complete remission, partial response, and stable disease. Overall tumor response could only be assessed as any response because response categories were not uniformly defined in the analyzed studies. In 14 articles, clinical

data were presented on tumor response and survival for 425 patients with HCC who had received Y90 RE. Treatment with resin microspheres (0.89) was associated with a significantly higher proportion of any response than glass microsphere treatment (0.78; p=.02). Median survival was reported in 7 studies, in which survival time was defined as survival from microsphere treatment or diagnosis or recurrence of HCC. Median survival from microsphere treatment varied between 7.1 months and 21.0 months, and median survival from diagnosis or recurrence ranged from 9.4 to 24.0 months.

Randomized Controlled Trials

Dhondt et al. (2022) reported on results from the Transarterial Radioembolization versus Chemoembolization for the Treatment of Hepatocellular Carcinoma (TRACE), an open-label, single-center, superiority RCT. (12) The primary endpoint was time to overall tumor progression, with study sample size calculations assuming a 20% improvement with RE. A planned interim analysis for efficacy was performed when 45 disease progression events were observed, at which point the null hypothesis would be rejected when the HR was greater than 2.60 or less than 0.39 or when the p value was less than .0024. Patients with unresectable Barcelona Clinic Liver Cancer stage A and B HCC were randomized to treatment with glass microsphere-based RE (n=38) or DEB-TACE (n=34). The median time to progression was 17.1 months and 9.5 months for RE and DEB-TACE groups, respectively (HR, 0.36; p=.002). With HR <0.39 for the primary end point in favor of RE at interim analysis, the null hypothesis was rejected, and the study was terminated on ethical grounds. Median progression-free survival (PFS) was 11.8 months in the RE arm and 9.1 months in the DEB-TACE arm (HR, 0.40; 95% CI, 0.24 to 0.67; p<.001). Downstaging led to transplant in 10 patients treated with RE and 4 patients treated with DEB-TACE. Median OS in RE and DEB-TACE groups was 30.2 months and 15.6 months, respectively (HR, 0.48; 95% CI, 0.28 to 0.82; p=.006).

Nonrandomized Comparative Studies

Facciorusso et al. (2020) performed a retrospective analysis that compared patients with HCC treated with RE plus sorafenib (n=45) with propensity score-matched patients treated with sorafenib alone (n=90). (13) No significant differences were identified in median OS (10 vs. 10 months; p=.711), median PFS (6 vs. 7 months; p=.992), and objective response rate (45.5% vs. 42.8%; p=1).

Padia et al. (2017) reported on a single-center, retrospective study (2010 to 2015) comparing segmental RE with segmental chemoembolization in 101 patients with localized, unresectable HCC not amenable to ablation. (14) Patients receiving chemoembolization had poorer Eastern Cooperative Oncology Group (ECOG) Performance Status ratings and Child-Pugh class while those receiving RE had larger and more infiltrative tumors. Overall complete remission was 84% with RE and 58% with chemoembolization (p=.001). Median PFS was 564 days and 271 days (p=.002), and median OS was 1198 days and 1043 days (p=.35), respectively, for the RE group and the chemotherapy group.

Soydal et al. (2016) retrospectively assessed outcomes for patients receiving RE and TACE for HCC. (15) Each group included 40 patients. RE patients had a mean survival of 39 months versus

31 months for TACE patients (p=.014). There were no significant differences in complication or disease recurrence rates.

Oladeru (2016) retrospectively analyzed Surveillance, Epidemiology, and End Results registry data, comparing survival outcomes for patients with HCC receiving RE with EBRT. (16) A total of 189 patients with unresectable HCC (77 receiving RE, 112 receiving EBRT) were treated between 2004 and 2011. Median OS for RE was 12 months and 14 months for EBRT. Median disease-specific survival was identical for both groups at 14 months. After adjustment for differences between patients, multivariable survival analysis showed no association between treatment and OS or disease-specific survival.

Gramenzi et al. (2015) conducted a retrospective cohort study comparing RE with the kinase inhibitor sorafenib for intermediate- or advanced-stage HCC. (17) Patients with HCC refractory to other therapies and no metastases or systemic chemotherapy were included, 74 of whom were treated with sorafenib and 63 with RE. Median OS between groups was similar (14.4 months for sorafenib-treated patients vs. 13.2 months for RE-treated patients). After propensity-score matching of 32 subjects in each group, there were no significant differences in median OS or 1-, 2-, and 3-year survival rates between groups.

Subsection Summary: Radioembolization for Unresectable Hepatocellular Carcinoma

Radioembolization has been compared with alternative treatments for HCC, including TACE, DEB-TACE, TACE plus EBRT, and sorafenib. Systematic reviews, RCTs, and nonrandomized comparative studies reported varied treatment superiority in tumor response and survival outcomes. Although rigorous comparative RCTs are lacking, if the active comparators are effective treatments for HCC, then these results are consistent with some degree of efficacy for RE in the treatment of HCC. In all studies reviewed, tumor response is observed, which may improve survival.

Radioembolization as a Bridge to Liver Transplantation for Unresectable Hepatocellular Carcinoma

Systematic Reviews

Kulik et al. (2018) published a systematic review of 18 comparative studies and 31 noncomparative studies that included patients with unresectable HCC who needed a liver transplant and received transplant alone or some type of bridging therapy as well (see Table 2). (18) Of the 18 comparative studies, 2 studies (n=257) reported on the incidence of dropout from transplantation wait lists, and patients receiving bridging therapy. This group had a reduced risk of dropout due to disease progression, compared with those receiving transplantation alone (RR, 0.32) (see Table 3). Between-group differences were not statistically significant for mortality (5 comparative studies; n=531) or recurrence rate (10 comparative studies; n=889). Subgroup analysis was conducted for types of bridging therapy: for all-cause mortality after transplantation, the RR was 1.124 with TAE compared with transplantation alone (1 cohort). For disease recurrence, the RR for this bridging therapy type was 2.374 compared with transplantation alone. No RCTs were identified, and most of the selected studies had a high risk of bias on patient selection.

Table 2. Characteristics of Systematic Reviews

Study	Dates	Trials	Participants[a]	Design
Kulik et al. (2018) (18)	1996-2016	49	Unresectable hepatocellular carcinoma	• 18 comparative • 31 noncomparative

[a] Patients needed liver transplantation and received transplant alone or bridging therapy in addition to transplant.

Table 3. Results of Systematic Reviews

Study	Dropout From Waitlist	Mortality	Recurrence Rate	Subgroup Analysis by Therapy Type	Comments
Kulik et al. (2018) (18)					
Comparative studies (N=18)	2 studies (n=257)	5 studies (n=531)	10 studies (n=889)		
	Reduced risk of dropout in patients with bridging therapy vs transplant alone (RR, 0.32; 95% CI, 0.06 to 1.85; I^2=0%)	Nonsignificant between-group difference	Nonsignificant between-group difference	All-cause mortality: TAE vs transplant alone, (RR 1.124; 95% CI, 0.675 to 1.873) Recurrence: TAE vs transplant alone, (RR, 2.374; 95% CI, 0.609 to 9.252)	No RCTs were identified; many studies had a high risk of bias for patient selection

CI: confidence interval; RCTs: randomized controlled trials; RR: relative risk; TAE: transarterial embolization.

Randomized Controlled Trials

Salem et al. (2016) reported on results of a phase 2 RCT comparing conventional TACE with TheraSphere RE (Y90) for treatment of unresectable, unablatable HCC. (19) Twenty-four patients were assigned to Y90 and 21 patients to TACE; the ultimate endpoint of treatment for these patients was liver transplantation. The primary outcome was time to progression using intention-to-treat analysis. Median follow-up was 17 months. In the TACE group, there were 7 transplants at a median of 9 months (range, 3 to 17 months). In the Y90 group, there were 13 transplants at a median of 9 months (range, 4 to 15 months). Median time to progression

exceeded 26 months in the Y90 group and 6.8 months in the TACE group (HR, 0.12; 95% CI, 0.03 to 0.56; p=.007). Median survival was 19 months with Y90 and 18 months in TACE (p=.99). Adverse events were similar between groups, with the exception of more diarrhea (21% vs. 0%) and hypoalbuminemia (58% vs. 4%) in the conventional TACE group. A limitation of the OS analysis was the censoring of the survival outcome at liver transplantation given that transplantation is related to the treatment effe3ct.

Kulik et al. (2014) reported on the results of a pilot RCT of Y90 RE with or without sorafenib for patients who had HCC and were awaiting liver transplantation. (20) The trial randomized 23 subjects; after accounting for losses due to self-withdrawal from the trial, failure to confirm HCC, and death, the modified intention-to-treat population included 10 subjects randomized to RE alone and 10 randomized to RE plus sorafenib. Overall, 17 of 20 patients underwent liver transplantation, with no difference in median time-to-transplant between groups. However, the addition of sorafenib was associated with increased peritransplant biliary complications and acute rejection.

Nonrandomized Studies

Salem et al. (2021) reported the results of the multicenter, single-arm, retrospective LEGACY trial investigating Y90 RE with TheraSphere for the treatment of solitary, unresectable HCC. (21) The aim of the study was to evaluate the objective response rate (ORR), and the duration of response based on modified RECIST criteria as evaluated by a blinded, independent, central review. Eligibility criteria included: solitary HCC ≤8 cm, Child-Pugh A cirrhosis, and ECOG performance status 0 to 1. Of 162 enrolled patients, 60.5% were ECOG 0 and RE served as neoadjuvant therapy for transplantation or resection in 21% and 6.8% of patients, respectively. The median follow-up duration was 29.9 months. The ORR (best response) was 88.3% (95% CI, 82.4% to 92.4%) with 62.2% (95% CI, 54.1% to 69.8%) exhibiting a duration of response of 6 months or greater. Three-year OS was 86.6% for all patients and 92.8% for neoadjuvant patients resected or transplanted. This study supported U.S. Food and Drug Administration (FDA) premarket approval of TheraSphere for use in HCC. (22)

Pellegrinelli et al. (2021) reported on an 8-year single-center experience utilizing RE for the treatment of patients with unresectable HCC (n=44), metastatic colorectal cancer (n=20), and intrahepatic cholangiocarcinoma (n=6). (23) Treatment with prior chemotherapy was reported in 48.6% of all patients, and RE-related grade 3 or higher adverse events impacted 17.1% of patients. Patients were treated with RE as a bridge to transplant (4.3%), for downstaging prior to surgical resection (15.7%), for ablative therapy (1.4%), and for palliative treatment (78.6%). Median follow-up was 32.1 months, during which disease progression occurred in 63 (90%) of all patients. Among patients with HCC at study end, complete and partial responses were achieved in 1 and 2 patients, respectively. Median OS was 16.1 months (range, 1.0 to 72.5 months) with no significant differences in survival among disease groups.

Gabr et al. (2020) performed a retrospective review that reported on long-term outcomes of liver transplantation for patients with HCC who were bridged or downstaged with RE. (24) From 2004 to 2018, 207 patients underwent transplantation after RE. The median OS from transplant

was 12.5 years, with a median time to liver transplantation of 7.5 months (interquartile range, 4.4 to 10.3 months). Overall, 169 patients were bridged and 38 were downstaged to liver transplant. The OS rates at 3, 5, and 10 years were 84%, 77%, and 60%, respectively.

Zori et al. (2020) performed a retrospective cohort analysis that compared patients with HCC undergoing bridging locoregional therapy with RE (n=28) to TACE (n=37) prior to liver transplant. (25) Three-year survival was not significantly different with RE versus TACE (92.9% vs. 75.7%; p=.052). However, microvascular invasion occurred in 3.6% versus 27% of patients treated with RE versus TACE (p=.013).

In a retrospective review, Tohme et al. (2013) reported on 20 consecutive HCC patients awaiting liver transplant who received RE as bridge therapy. (26) When RE began, Milan criteria were met by 14 patients and sustained until transplantation. Of the 6 patients who did not meet Milan criteria initially, RE was able to downstage 2 patients to meet Milan criteria. After RE, the median time to liver transplant was 3.5 months. Complete or partial radiologic response to RE, assessed using modified Response Evaluation Criteria In Solid Tumors (RECIST), occurred in 9 patients. Additionally, on pathologic examination, 5 patients had no evidence of viable tumor whose disease met the Milan criteria.

Ramanathan et al. (2014) reported on various therapies, including RE, for 715 HCC patients of whom 231 were intended for transplant. (27) In the intention-to-treat transplantation arm, 60.2% received a transplant. Survival rates posttransplant were 97.1% and 72.5% at 1 and 5 years, respectively. Tumor recurrence rates were 2.4%, 6.2%, and 11.6% at 1, 3, and 5 years, respectively.

Lewandowski et al. (2009) compared the efficacy of RE with chemoembolization in downstaging 86 patients with HCC from stage T3 to T2 (potentially making these patients liver transplant candidates). (28) Patients were treated with RE using Y90 microspheres (n=43) or TACE (n=43). Median tumor sizes were similar between treatment groups (5.7 cm for TACE vs. 5.6 cm for RE). Partial response rates were 61% for RE and 37% for TACE, with downstaging from T3 to T2 in 58% of patients treated with RE versus 31% with TACE (p<.05).

Subsection Summary: Radioembolization as a Bridge to Liver Transplantation for Unresectable Hepatocellular Carcinoma

A systematic review, RCTs, and nonrandomized studies have shown that bridging therapy can support patients with unresectable HCC until a liver transplant is available. Radioembolization is among the therapies that can provide a bridge to transplant.

Radioembolization for Unresectable Intrahepatic Cholangiocarcinoma

Clinical Context and Therapy Purpose

The purpose of RE in individuals who have unresectable intrahepatic cholangiocarcinoma (ICC) is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

Populations
The relevant population of interest is individuals with unresectable ICC. Cholangiocarcinomas are tumors that arise from the epithelium of the bile duct and are separated into intrahepatic and extrahepatic types. ICC appears in the hepatic parenchyma and is also known as peripheral cholangiocarcinoma. Approximately 6,000 cases of ICC are diagnosed annually in the U.S., with an estimated incidence of 1.49 cases per 100,000 individuals. (29)

Interventions
The treatment being considered is RE. RE may also be referred to as SIRT or TARE.

Comparators
The following are comparators to RE in the treatment of unresectable ICC: standard of care, usually palliative. Resection is the only treatment with a potentially curative effect, and 5-year survival rates have ranged from 50% to 70%. (30) Patients with unresectable disease may select among fluoropyrimidine- or gemcitabine-based chemotherapy plus a monoclonal antibody, fluoropyrimidine chemoradiation, or best supportive care. Arterially directed locoregional therapies for unresectable presentations, including hepatic arterial infusion (HAI), radiofrequency ablation, TACE, or DEB-TACE, may also be considered.

Outcomes
The general outcomes of interest are OS, functional outcomes, quality of life, and treatment-related morbidity (see Table 4). Outcomes of interest for palliative care include quality of life measures and relief of pain, pruritus, jaundice, and biliary obstruction.

Table 4. Outcomes of Interest for Individuals with Unresectable Intrahepatic Cholangiocarcinoma

Outcomes	Details
Treatment-related morbidity	Outcomes of interest include complete remission, partial response, PFS, OS, and stable disease [Timing: ≥3 months]

OS: overall survival; PFS: progression-free survival.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs.
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Systematic Reviews

Schartz et al. (2022) reported on the efficacy and survival profile of RE for unresectable ICC. (31) Twenty-one studies representing 921 patients with follow-up duration from 3 to 36 months were evaluated, finding an overall disease control rate of 82.3% (95% CI, 76.7% to 87.8%; I^2 = 81%), median PFS of 7.8 months (95% CI, 4.2 to 11.3; I^2 = 94%), and median OS of 12.7 months (95% CI, 10.6 to 14.8; I^2 = 62%). Patients were downstaged for surgical resection in 11% of cases (95% CI, 6.1% to 15.9%; I^2 = 78%). The analysis is limited by the inclusion of primarily retrospective study designs and considerable clinical and methodologic heterogeneity.

Edeline et al. (2021) conducted a systematic review and pooled analysis of locoregional therapies in patients with unresectable ICC. (32) Ninety-three studies were pooled for analysis, representing 15 cohorts (n=645) for ablation, 18 cohorts (n=541) for EBRT, 27 cohorts (n=1232) for RE, 22 cohorts for TACE, and 16 cohorts (n=331) for HAI. Pooled weighted mean PFS was 15.6, 7.8, 15.0, and 10.1 months for EBRT, RE, TACE, and HAI, respectively. Pooled weighted mean OS was 30.2, 18.9, 14.1, 15.9, and 21.3 months for ablation, EBRT, RE, TACE, and HAI, respectively. The authors noted that the quality of the studies was insufficient to derive strong recommendations, with the exception of consistently good outcomes for ablation. Instead, the pooled results are presented to establish benchmarks for the design of future clinical trials.

Yu et al. (2021) reported on outcomes in a systematic review and meta-analysis of RE compared to EBRT in the treatment of unresectable ICC. (33) Between 2000 and 2020, 29 and 20 studies representing 732 and 443 patients were identified for RE and EBRT groups, respectively. From initial treatment, median OS for RE and EBRT was 12.0 months (95% CI, 10.8 to 14.6 months) and 13.6 months (95% CI, 11.1 to 16.0 months), respectively. As first-line therapy, the median OS for RE was 36.1 months (95% CI, 20.6 to 39.5 months) compared to 11.0 months (95% CI, 9.3 to 13.6 months) for EBRT. Downstaging to surgery among treatment-naive patients was reported in 30.5% and 18.3% of RE and EBRT groups, respectively. Patients treated with RE experienced higher rates of post-embolization abdominal pain, ulcer, nausea, anorexia, thrombocytopenia, hyperbilirubinemia, and hypoalbuminemia. In contrast, EBRT was associated with higher rates of anemia and neutropenia. The authors noted that comparison between groups is limited due to significant population and treatment heterogeneity.

Mosconi et al. (2021) published a systematic review and meta-analysis comparing the treatment efficacy of RE (18 studies; n=789) and TACE (13 studies; n=906). (34) The median survival was 13.5 months (95% CI, 11.4 to 16.1 months) and 14.2 months (95% CI, 11.6 to 17.6 months) for RE and TACE groups, respectively. The survival difference between groups was negligible at 2 and 3 years. Clinical adverse events occurred at a higher frequency in patients treated with TACE (58.5%) compared to RE (43.0%).

Boehm et al. (2015) conducted a systematic review comparing hepatic artery-based therapies, including HAI, TACE, DEB-TACE, and Y90 RE, for unresectable ICC. (35) Of 20 studies that met inclusion criteria, 5 evaluated Y90 RE. Median OS across studies was 22.8 months for HAI, 13.9 months for RE, 12.4 months for TACE, and 12.3 months for DEB-TACE. Complete remission or partial response occurred in 56.9% of patients treated with HAI compared with 27.4% of those treated with RE and 17.3% of those treated with TACE.

Noncomparative Studies

Robinson et al. (2023) reported outcomes for 95 patients with unresectable ICC who were treated with Y90 RE. (36) Data were obtained from the Radiation-Emitting SIR-Spheres in Non-resectable (RESiN) liver tumor registry; patient demographic information was not summarized in this publication. Multifocal tumors were present in 60% of patients and 27% had extrahepatic tumors. The median OS was 14 months (95% CI, 12 to 22 months) and the OS at 3, 6, 12, and 24 months was 94%, 80%, 63%, and 34%, respectively. Imaging response at 6 months predicted OS (HR, 0.39; p=.008). Grade 3/4 bilirubin toxicities and Grade 3 albumin toxicity were noted in 7% and 1.4% of patients, respectively.

Chan et al. (2022) published results from a phase 2, multicenter (China, Singapore, and Thailand) study evaluating the efficacy and safety of Y90 SIRT followed by chemotherapy with gemcitabine and cisplatin in patients with unresectable ICC without prior treatment with chemotherapy or radiation. (37) The median age of patients was 64 years and 63% were male. A total of 24 patients completed SIRT and 16 of them underwent subsequent chemotherapy. The median OS was 13.6 months (95% CI, 5.4 to 21.6) in the intention-to-treat (ITT) population (i.e., patients receiving at least one cycle of SIRT regardless of receiving chemotherapy or not; n=24) and 21.6 months (95% CI, 7.3 to 25.2) among the 16 patients who underwent subsequent chemotherapy. In the ITT population, the overall response rate was 16.7% (95% CI, 1.8% to 31.6%) and the disease control rate was 58.3% (95% CI, 38.6% to 78.1%). Among the 16 patients who received subsequent chemotherapy, the overall response rate was 25% (95% CI, 3.8% to 46.2%) and the disease control rate was 75% (95% CI, 53.8% to 96.2%).

A few studies have evaluated RE with chemotherapy in the first-line setting.

Kis et al. (2023) published results from a prospective feasibility study evaluating the efficacy and safety of Y90 RE in the first-line setting in 24 patients with unresectable ICC without extrahepatic metastasis, and who never received chemotherapy, liver embolization, or radiation therapy. (38) The mean age of patients was 72 years, 50% were male, and all but 1 were White. Results demonstrated that the median liver PFS was 5.5 months (95% CI, 3.9 to 7.0 months) and the median OS from the RE treatment was 19.4 months (95% CI, 5.0 to 33.7 months).

Edeline et al. (2019) published results from the phase 2, MISPHEC trial (Yttrium-90 Microspheres in Cholangiocarcinoma), which included 41 patients with unresectable ICC treated in the first-line setting with cisplatin, gemcitabine, and RE in French centers with experience with glass microspheres. (39) The mean age of included patients ranged from 67 to 71 years and 60% were male. Fifteen (37%) patients underwent more than 1 RE treatment. The response rate at 3 months according to RECIST version 1.1 criteria was 39% (90% CI, 26% to 53%) according to a local review, with a disease control rate of 98%. After a median follow-up of 36 months, the median PFS was 14 months (95% CI, 8 to 17 months) and the median OS was 22 months (95% CI, 14 to 52 months). Of 41 patients, 29 (71%) experienced grade 3 and 4 toxic events, including neutropenia (51%), thrombocytopenia (24%), asthenia (22%), anemia (20%),

and abdominal pain (12%). Fourteen patients experienced hepatic failure, including 5 nonreversible cases in patients with cirrhosis who had received whole-liver RE. Nine patients (22%) were downstaged to surgical intervention, with 8 cases achieving an R0 surgical resection. A follow-up phase 3 trial randomizing patients with unresectable ICC to chemotherapy alone or RE followed by chemotherapy in the first-line setting was terminated early due to low enrollment (NCT02807181).

Case Series

Numerous small case series (range, 19 to 115 patients) evaluating RE for unresectable ICC have been published. (40-52) Predominantly retrospective case reviews have assessed heterogeneous populations, making it difficult to ascertain which patients may benefit most from RE. Populations within and between studies have differed in terms of performance status, tumor distribution (e.g., unilobar vs. bilobar [44, 49]), morphology (e.g., infiltrative), metastatic disease (e.g., lymph node or extrahepatic metastases), prior treatments (e.g., chemotherapy, [42, 46] surgery, and other liver-directed therapies), treatment setting (e.g., neoadjuvant, [51] palliative [44]), and comorbidities (e.g., cirrhosis [41]). Several studies have reported on resection outcomes following downstaging treatment with RE alone (41, 45, 49, 51) or in combination with chemotherapy. (40, 44) One study compared outcomes with glass versus resin microspheres, finding no significant difference in OS between groups. (41) Across series, the median survival in patients treated with RE ranged from 6 to 22 months. Several studies identified favorable subgroups with respect to OS, reporting prolonged outcomes in treatment-naive patients, (43) and for tumor burden 25% or less, (46, 50) peripheral tumor type, (48, 49) and an ECOG performance score of 0. (46, 48, 49)

Section Summary: Intrahepatic Cholangiocarcinoma

The evidence for RE in ICC primarily consists of retrospective case reviews. Across studies, the median survival in patients treated with RE ranged from 6 to 22 months. Side effects are common but generally mild. Patient populations in these studies were heterogeneous, varying in performance status, prior interventions, presence of extrahepatic disease, and tumor distribution and morphology. Therefore, in the absence of data in well-defined patient populations, it is difficult to ascertain which patients are most likely to derive benefits from RE. A phase 2 study evaluating the use of RE with chemotherapy in the first-line setting reported a response rate of 39% and a disease control rate of 98%. Another phase 2 study evaluating RE with or without subsequent chemotherapy in patients without prior treatment with chemotherapy or radiation found overall response rates of 25% and 16.7% in those who received RE with and without chemotherapy, respectively; the disease control rates were 75% and 58.3% among those who received RE with and without chemotherapy, respectively. An RCT investigating the use of RE in the neoadjuvant setting is currently ongoing.

Radioembolization for Unresectable Neuroendocrine Tumors

Clinical Context and Therapy Purpose

The purpose of RE in individuals who have unresectable neuroendocrine tumors is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

Populations
The relevant population of interest is individuals with unresectable neuroendocrine tumors. These tumors are an uncommon, heterogeneous group of mostly slow-growing, hormone-secreting malignancies, with an average patient age of 60 years. Primary neuroendocrine tumors vary in location, but most are either carcinoids (which most commonly arise in the midgut area) or pancreatic islet cells. The estimated prevalence of neuroendocrine tumors in the U.S. is 170,000 individuals. (53)

Interventions
The treatment being considered is RE. RE may also be referred to as SIRT or TARE.

Comparators
The following are comparators to RE in the treatment of unresectable neuroendocrine tumors: standard of care, usually palliative. Conventional therapy is generally considered to be palliative supportive care, to control, eradicate, or debulk hepatic metastases, often to palliate carcinoid syndrome or local pain from liver capsular stretching. Therapies for unresectable metastatic neuroendocrine tumors include medical (somatostatin analogues like octreotide), systemic chemotherapy, ablation (radiofrequency or cryotherapy), TAE or TACE, or radiotherapy. Although patients often achieve symptom relief with octreotide, the disease eventually becomes refractory, with a median duration of symptom relief of approximately 13 months, with no known effect on survival. Systemic chemotherapy for these tumors has revealed that: 1) modest response rates are of limited duration; 2) it is more effective for pancreatic neuroendocrine tumors than carcinoids; and 3) it is frequently associated with significant toxicity. (54) Chemoembolization has shown response rates of nearly 80%, but the effect is of short duration, and a survival benefit has not been demonstrated. (54)

Outcomes
The general outcomes of interest are OS, functional outcomes, quality of life, and treatment-related morbidity. Although considered indolent tumors at the time of diagnosis, up to 75% of patients experienced liver metastases and with metastases to the liver, 5-year survival rates are less than 20%. Surgical resection of the metastases is considered the only curative option; however, less than 10% of patients are eligible for resection, because most patients have multiple diffuse lesions.

Carcinoid tumors, particularly if they metastasize to the liver, can result in excessive vasoactive amine secretion including serotonin and are commonly associated with the carcinoid syndrome (diarrhea, flush, bronchoconstriction, right valvular heart failure).

The timeframe for outcome measures varies from several months to 5 years.

<u>Study Selection Criteria</u>
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs.
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Systematic Reviews

Ngo et al. (2021) conducted a meta-analysis of 6 retrospective cohort studies with a total of 643 patients treated with TACE (n=422) or RE (n=221). (55) Patients treated with TACE exhibited significantly improved OS (OR, 1.92; 95% CI, 1.14 to 3.22; p=.014) compared to those treated with RE. No significant differences in hepatic PFS (p=.96) or overall tumor response (p=.99) were observed. Although the overall proportion of patients with unresectable disease is unclear, the history of resection or ablation in the 2 groups was not significantly different (OR, 1.20; 95% CI, 0.71 to 2.02; p=.49). Patients receiving RE were more likely to have received prior systemic chemotherapy (OR, 0.48; 95% CI, 0.27 to 0.83; p=.009) and octreotide therapy (OR, 0.50; 95% CI, 0.30 to 0.84; p=.009).

Frilling et al. (2019) reported results from a case series of 24 patients that were then included in a meta-analysis of patients treated with for neuroendocrine liver metastases. (56) Overall, 26 additional studies were included in the meta-analyses, which reported a fixed-effects weighted averages for ORR of 51% (95% CI, 47% to 54%) and disease control rate (complete response, partial response, or stable disease) of 88% (95% CI, 85% to 90%).

Devcic et al. (2014) conducted a meta-analysis of studies evaluating RE for liver-dominant metastatic neuroendocrine tumors. (57) The analysis included 12 studies that provided RECIST data for hepatic metastatic neuroendocrine tumors treated with RE. For Y90 RE with resin microspheres only, objective radiographic response rates (complete remission or partial response by RECIST) ranged from 12% to 80%, with a random effects weighted average of 50% (95% CI, 38% to 62%). Disease control rates (complete remission, partial response, stable disease) ranged from 62% to 100%, with a random-effects weighted average of 86% (95% CI, 78% to 92%).

Nonrandomized Comparative Studies

Egger et al. (2020) performed a retrospective cohort analysis comparing patients with neuroendocrine liver metastases treated with RE (n=51) or TACE (n=197). (58) Between RE and TACE, there were no statistically significant differences in overall morbidity (13.7% vs. 22.6%, respectively; p=.17), grade 3/4 complication (5.9% vs. 9.2%; p=.58), 90-day mortality (9.8% vs. 5.2%; p=.21), median OS (35.9 months vs. 50.1 months; p=.3), or PFS (15.9 months vs. 19.9 months; p=.37). However, the disease control rate was greater for TACE compared with RE (96% vs. 83%; p<.01).

Engelman et al. (2014) retrospectively compared transarterial, liver-directed therapies, including RE, hepatic artery embolization (HAE), and hepatic artery chemoembolization (HACE), in 42 patients treated for metastatic neuroendocrine tumors. (59) Treatment decisions were at the discretion of the referring physician and interventional radiologist, but the decision to proceed with therapy was typically based on the progression of symptoms nonresponsive to octreotide therapy or rapid progression of liver tumor burden on imaging. Seventeen patients had HACE, 13 had HAE, and 12 had RE. Among the 27 patients with symptoms related to their liver metastases, there were no statistically significant differences in symptom improvement at 3 months after first liver-directed therapy across treatment modalities (6/13 for HACE; 4/8 for HAE; 5/6 for RE; p=.265). There were no statistically significant differences between treatment modalities in radiographic response at 6 months postprocedure (p=.134), time to progression (p=.968), or OS (p=.30).

Case Series

Rhee et al. (2008) reported on the results of a multicenter, open-label, phase 2 study that assessed the safety and efficacy of RE, using glass or resin microspheres, in 42 patients with metastatic neuroendocrine liver disease who had failed prior treatment(s), including medical (e.g., octreotide), surgical resection, bland or chemoembolization, and radiofrequency ablation or cryoablation. (60) RECIST criteria were used to assess tumor response, which showed 92% of glass patients and 94% of resin patients had a partial response or had a stable disease at 6 months after treatment. Median survival was 22 months for glass and 28 months for resin.

Cao et al. (2010) reported on outcomes for 58 patients with unresectable neuroendocrine liver metastases from 2 hospitals who were treated with RE from 2003 to 2008. (61) Response was assessed with radiographic evidence before and after RE and measured using RECIST guidelines. Systemic chemotherapy was routinely given at a single institution. Mean patient age at the time of RE was 61 years (range, 29 to 84 years). Primary tumor site varied and included small bowel, pancreas, colon, thyroid, lung, and unknown. Thirty-one patients underwent surgical resection of their primary tumor, which was classified as a low grade in 15, intermediate grade in 7, and high grade in 7. Forty-three percent of patients had extrahepatic metastatic disease at study entry. Median follow-up was 21 months (range, 1 to 61 months). Fifty-one patients were evaluable, and 6 achieved complete remission, 14 had a partial response, 14 had stable disease, and 17 experienced disease progression. OS rates at 1, 2, and 3 years were 86%, 58%, and 47%, respectively. Median survival was 36 months (range, 1 to 61 months). Prognostic factors for survival included the extent of tumor involvement of the liver, radiographic response to treatment, the presence of extrahepatic disease at the time of RE, the histologic grade of the tumor, and whether patients responded to RE.

King et al. (2008) reported on outcomes for patients treated in a single institution prospective study. (54) Thirty-four patients with unresectable neuroendocrine liver metastases were given radioactive microspheres (SIR-Spheres) and concomitant 7-day systemic infusion of fluorouracil (5-FU), between 2003 and 2005. Mean patient age was 61 years (range, 32 to 79 years). Mean follow-up was 35.2 months. Primary tumor sites varied and included bronchus (n=1), thyroid (n=2), gastrointestinal (n=15), pancreas (n=8), and unknown (n=8). Subjective changes from

baseline hormone symptoms were reported every 3 months. Twenty-four (71%) patients had at baseline assessment symptoms of carcinoid syndrome, including diarrhea, flushing, or rash. At 3 months, 18 (55%) of 33 patients reported improvements in symptoms, as did 16 (50%) of 32 at 6 months. Radiologic tumor response was observed in 50% of patients and included 6 (18%) complete remission and 11 (32%) partial response. Mean OS was 29.4 months.

Kennedy et al. (2008) retrospectively reviewed 148 patients from 10 institutions with unresectable hepatic metastases from neuroendocrine tumors. (62) All patients had completed treatment of the primary tumor and metastatic disease and were not excluded based on prior therapy. The total number of resin microsphere treatments was 185, with retreatment in 22.3% of patients (19.6% received 2 treatments, 2.7% received 3 treatments). All patients were followed using imaging studies at regular intervals to assess tumor response (using either World Health Organization or RECIST criteria) until death, or they were censored if a different type of therapy was given after the microspheres. Median follow-up was 42 months. By imaging, response rates were a stable disease in 22.7%; partial response in 60.5%; complete remission in 2.7%; and progressive disease in 4.9%. Hepatic and extrahepatic metastases contributed to death in most patients, with 7% lost to follow-up. Median survival was 70 months.

Additional case series in patients with treatment-refractory, unresectable neuroendocrine hepatic metastases have shown tumor response and improvement in clinical symptoms with RE. (63-67)

Section Summary: Unresectable Neuroendocrine Tumors

The available comparative evidence for the use of RE to treat unresectable neuroendocrine tumors primarily consists of nonrandomized retrospective study designs. A 2019 meta-analysis reported fixed-effects weighted averages for objective response rate of 51% (95% CI, 47% to 54%) and disease control rate (complete response, partial response, or stable disease) of 88% (95% CI, 85% to 90%). In a small nonrandomized comparative study of RE, HAE, and HACE, no statistically significant differences in radiographic response, time to progression, and OS were observed, suggesting comparable efficacy.

Radioembolization for Unresectable Intrahepatic Metastases from Colorectal Carcinoma and Prior Treatment Failure

Clinical Context and Therapy Purpose

The purpose of RE in individuals who have unresectable intrahepatic metastases from CRC and prior treatment failure is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

Populations

The relevant population of interest is individuals with unresectable intrahepatic metastases from CRC and prior treatment failure. Fifty to 60 percent of patients with CRC will develop metastases, either synchronously or metachronously. Select patients with liver-only metastases

that are surgically resectable can be cured, with some reports showing 5-year survival rates exceeding 50%. The emphasis of treating these patients with the potentially curable disease is complete removal of all tumors with negative surgical margins. Most patients diagnosed with the metastatic colorectal disease are initially classified as having unresectable disease. In some with metastatic disease limited to the liver, preoperative chemotherapy is sometimes used to downstage the metastases from metastatic lesions to resectable lesions (conversion chemotherapy).

Interventions
The treatment being considered is RE. RE may also be referred to as SIRT or TARE.

Comparators
The following are comparators to RE in the treatment of unresectable intrahepatic metastases from CRC and prior treatment failure: standard of care, usually palliative. In patients with unresectable disease, the primary treatment goal is palliative, with a survival benefit shown in both second- and third-line systemic chemotherapy. (68) Recent advances in chemotherapy, including oxaliplatin, irinotecan, and targeted antibodies like cetuximab, have doubled the median survival in this population from less than 1 year to more than 2 years. Palliative chemotherapy using combined systemic and HAI may increase disease-free intervals for patients with unresectable hepatic metastases from CRC.

Outcomes
The general outcomes of interest are OS, functional outcomes, quality of life, and treatment-related morbidity (see Table 5).

Table 5. Outcomes of Interest for Individuals with Unresectable Intrahepatic Metastases from Colorectal Cancer and Prior Treatment Failure

Outcomes	Details
Treatment-related morbidity	Outcomes of interest include complete remission, partial response, OS, PFS, and stable disease [Timing: ≥3 months]

OS: overall survival; PFS: progression-free survival.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs.
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Systematic Reviews

In a systematic review, Saxena et al. (2014) evaluated 20 experimental and observational studies on RE for chemoresistant, unresectable CRC liver metastasis (N=979). (69) They included 2 RCTs (Gray et al. [2001] [70]; Hendlisz et al. [2010] [71]; described below), 5 non-RCTs or well-designed cohort studies, and 13 observational studies. After RE, the average reported complete remissions and partial response rates from 16 studies were 0% (range, 0% to 6%) and 31% (range, 0% to 73%), respectively. Nine months was the median time to intrahepatic progression (range, 6 to 16 months). In 11 studies reporting on OS, the median survival time was 12 months (range, 8.3 to 3.6 months).

Rosenbaum et al. (2013) evaluated 13 relevant studies in a systematic review on RE as monotherapy and 13 studies on RE combined with chemotherapy for chemoresistant, unresectable CRC liver metastasis. (72) Complete remission, partial response, and stable disease rates ranged from 29% to 90% with RE only and from 59% to 100% for RE plus chemotherapy. At 12 months, survival rates ranged from 37% to 59% with RE only and from 43% to 74% for RE plus chemotherapy.

Three earlier systematic reviews, published in 2010 and 2009, are briefly noted; all include RCTs by Gray et al. (2001) (70) and Van Hazel et al. (2004). (73) The 2010 report by the California Technology Assessment Forum assessed 25 studies, including the 2 RCTs, a retrospective comparative study (n=36), and 21 case series. (68) The review concluded that the RCT results were encouraging but not definitive. A Cochrane review by Townsend et al. (2009) assessed the efficacy and toxicity of RE, alone or with systemic or regional hepatic artery chemotherapy. (74) Townsend et al. (2009) found insufficient evidence to demonstrate that RE improved survival or quality of life. (74) The meta-analysis by Vente et al. (2009) included 19 studies with a total of 792 patients. A meta-regression model found a tumor response rate of 80% in the salvage setting and 90% at first-line neoadjuvant therapy. Median survival after RE ranged from 6.7 to 17 months, irrespective of microsphere type, chemotherapy protocol, or use as salvage or first-line therapy. (11)

Randomized Controlled Trials

Mulcahy et al. (2021) reported on outcomes from the Efficacy Evaluation of TheraSphere Following Failed First Line Chemotherapy in Metastatic Colorectal Cancer (EPOCH) trial, an open-label phase 3 trial studying the impact of RE with TheraSphere in combination with second-line systemic chemotherapy for colorectal liver metastases in 428 patients from 95 centers in North America, Europe, and Asia. (75) Patients who had progressed on first-line chemotherapy were randomized 1:1 to receive second-line oxaliplatin- or irinotecan-based chemotherapy with (n=215) or without RE (n=213). The study was designed to detect a HR of 0.71 for PFS and 0.65 for hepatic PFS favoring RE plus chemotherapy. The median PFS was 8.0 months (95% CI, 7.2 to 9.2 months) and 7.2 months (95% CI, 5.7 to 7.6 months), respectively, with a corresponding HR of 0.69 (95% CI, 0.54 to 0.88; p=.0013) favoring RE. The median hepatic PFS was 9.1 months (95% CI, 7.8 to 9.7 months) and 7.2 months (95% CI, 5.7 to 7.6 months) for patients treated with and without RE, respectively (HR, 0.59; 95% CI, 0.46 to 0.77; p<.0001). Delayed progression was also observed for tumors with *KRAS* mutation, left-sided primary tumor, hepatic tumor burden of 10% to 25%, 3 or fewer lesions, the addition of a

biologic agent, and resected primary. Median OS was 14.0 months (95% CI, 11.8 to 15.5 months) and 14.4 months (95% CI, 12.8 to 16.1 months; p=.7229) for the RE and chemotherapy groups, respectively (HR, 1.07; 95% CI, 0.86 to 1.32). However, it was noted that the study was not designed or powered for OS and the outcome may be confounded by subsequent locoregional therapies including RE in the control arm. The frequency of grade 3 adverse events was higher with the addition of RE to chemotherapy (68.4% vs. 49.3%). Overall, the investigators noted that the addition of RE to chemotherapy resulted in a statistically significant delay of disease progression. However, further research will be pursued to better identify patients who might benefit most from treatment, as well as dosimetric considerations to optimize the risk-benefit profile.

A phase 3 RCT by van Hazel et al. (2016) compared modified fluorouracil, leucovorin, and oxaliplatin (FOLFOX) chemotherapy and FOLFOX chemotherapy plus RE with SIR-Spheres in 530 patients with chemotherapy-naive liver-dominant metastatic disease. (76) The use of bevacizumab was allowed with FOLFOX chemotherapy, at the investigator's discretion. The primary endpoint was overall (any site) PFS. Secondary endpoints included liver-specific outcomes such as PFS in the liver, tumor response rate, and liver resection rate. The primary endpoint of PFS at any site showed no difference between groups (10.6 months for RE vs. 10.2 months for control; HR, 0.93; p=.43). Secondary endpoints of median PFS in the liver and objective response rate for RE in the liver versus controls were improved in the RE group (liver PFS, 20.5 months vs. 12.6 months; liver response rate, 78.7% vs. 68.8%), all respectively. This finding was consistent irrespective of tumor burden, bevacizumab therapy, or performance status. Wasan et al. (2017) analyzed OS from this study in combination with 2 other studies of chemotherapy with and without RE in the first-line setting. (77) Overall, 549 patients were randomly assigned to FOLFOX alone and 554 patients were assigned FOLFOX plus RE. The OS was not significantly different between groups (HR, 1.04; 95% CI, 0.90 to 1.19). Wolstenholme et al. (2020) published a follow-up analysis of health-related quality of life (HRQOL) measures as assessed by the 3-level EQ-5D, European Organisation for Research and Treatment of Cancer Quality of Life (EORTC QLQ-C30), and EORTC Colorectal Liver Metastases cancer module (EORTC QLQ-LMC21). (78) HRQOL was statistically significantly lower in RE + FOLFOX patients at ≤3 months after administration according to all 3 instruments, but these differences were not deemed clinically important. No clinically important differences were observed over the 2-year follow-up period.

The RCT by Gray et al. (2001) randomized 74 patients with bilobar unresectable liver metastases to monthly HAI with 5-FU alone or to 5-FU plus a single infusion of Y90 microspheres. (70) Accrual was halted early, entering 74 patients rather than the planned 95 at the discretion of the investigator rather than by planned data monitoring board oversight. To monitor responses to therapy, investigators serially measured serum levels of carcinoembryonic antigen and estimated tumor cross-sectional area and volume from repeated computerized tomography scans read by physicians blinded to treatment assignment. For HAI plus RE vs. HAI, they reported increased overall responses (complete remission plus partial response) measured by area (44% vs. 18%; p=.01) and volume (50% vs. 24%; p=.03), or by serum carcinoembryonic antigen levels (72% vs. 47%; p=.004), all respectively. They also

reported increased time to progression detected by increased area (9.7 months vs. 15.9 months; p=.001) or volume (7.6 months vs. 12.0 months; p=.04), both respectively. Treatment-related complications (grades 3 to 4) included 23 events in each arm (primarily changes in liver function tests). While in this trial, response rate and time to progression after RE plus HAI appeared superior to the same outcomes after HAI alone, results for the plus HAI group are within the range reported by other randomized trials of HAI in comparable patients. (79, 80)

A phase 2 RCT (2004) by the same research group assessed 21 patients with advanced colorectal liver metastases; a total of 11 patients received systemic chemotherapy (fluorouracil and leucovorin) plus RE, and 10 received systemic chemotherapy alone. (73) Disease time to progression was greater in those receiving combination therapy (18.6 months vs. 3.6 months, respectively; p<.001).

A phase 3 RCT by Hendlisz et al. (2010), which assessed 46 patients, compared intravenous 5-FU plus RE (SIR-Spheres) with intravenous 5-FU alone in CRC metastatic to the liver and refractory to standard chemotherapy. (71) The time to liver progression (the primary outcome) was significantly longer in the group receiving SIR-Spheres (2.1 months vs. 5.5 months, respectively; p=.003). After progression, patients received further treatment, including 10 in the 5-FU alone arm who received RE. There was no difference in median survival (7.3 months vs. 10.0 months, respectively; p=.80).

Nonrandomized Comparative Studies

Mokkarala et al. (2019) performed a propensity score-matched retrospective analysis of patients with colorectal metastases treated with DEB-TACE (n=47) or RE (n=155). (81) Extra-hepatic metastasis was more frequent with DEB-TACE (68.1% vs. 47.7%; p=.014), as was occurrence of ≥10 liver lesions (42.2% vs. 68.8%; p=.001). Toxicity was not significantly different between DEB-TACE and RE (27% vs. 9.1%, respectively; p=.057). Treatment with DEB-TACE was not a prognostic factor for survival (HR, 0.94; 95% CI, 0.54 to 1.65).

Seidensticker et al. (2012) published a retrospective, matched-pair comparison of RE plus best supportive care with best supportive care alone for patients with chemorefractory, liver-dominant colorectal metastases (n=29 in each group). (82) Patients were matched on tumor burden, prior treatments, and additional clinical criteria. Results showed prolongation of survival in patients who received RE (median survival, 8.3 months vs. 3.5 months; p<.001; HR, 0.3; 95% CI, 0.16 to 0.55; p<.001). Adverse events were considered generally mild-to-moderate and manageable.

Section Summary: Unresectable Intrahepatic Metastatic Colorectal Carcinoma

The evidence for the use of RE to treat unresectable intrahepatic metastatic CRC includes systematic reviews, RCTs, and nonrandomized comparative studies. The EPOCH RCT compared chemotherapy with or without RE in 428 patients who had progressed on first-line chemotherapy, finding that the addition of RE significantly prolonged the primary endpoints of PFS (HR, 0.69; 95% CI, 0.54 to 0.88) and hepatic PFS (HR, 0.59; 95% CI, 0.46 to 0.77) in the second-line setting. While studies of patients with prior chemotherapy failure have not shown

definitive superiority of RE compared with alternatives in terms of survival benefit, they tend to show greater tumor response and significantly delayed disease progression, particularly with the combined use of RE with chemotherapy.

Radioembolization for Unresectable Intrahepatic Metastases from Other Cancers

Clinical Context and Therapy Purpose

The purpose of RE in individuals who have unresectable intrahepatic metastases from other cancers is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

Populations

The relevant population of interest is individuals with unresectable intrahepatic metastases from other cancers.

Interventions

The treatment being considered is RE. RE may also be referred to as SIRT or TARE.

Comparators

The comparator of interest is standard of care. Comparators for RE may also include liver-directed therapies such as HAI chemotherapy.

Outcomes

The general outcomes of interest are OS, functional outcomes, quality of life, and treatment-related morbidity (see Table 6).

Table 6. Outcomes of Interest for Individuals with Unresectable Intrahepatic Metastases from Other Cancers (e.g., Breast, Melanoma, Pancreatic)

Outcomes	Details
Treatment-related morbidity	Outcomes of interest include complete remission, partial response, PFS, OS, and stable disease [Timing: ≥3 months]

OS: overall survival; PFS: progression-free survival.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs.
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Metastatic Intrahepatic Breast Cancer

Most studies on the use of RE for metastatic breast cancer have evaluated the use of RE alone (i.e., not in combination with chemotherapy) either between lines of chemotherapy or in individuals refractory to standard of care chemotherapy. (83)

Systematic Reviews

Liu et al. (2022) published a systematic review and meta-analysis assessing the evidence for Y90 SIRT in liver metastatic breast cancer. (84) A total of 24 studies (N=412) were included, most of which were retrospective or non-comparative. Patient demographic information was not summarized in this publication. The median survival time after SIRT was 9.8 months (95% CI, 9 to 11.6 months). The cumulative OS rates at 6 months and 1, 2, and 3 years were 65.6% (95% CI, 60.8% to 70.0%), 39.0% (95% CI, 34.3% to 43.7%), 13.3% (95% CI, 10.3% to 16.8%), and 4.4% (95% CI, 2.7% to 6.6%), respectively. Patients who had a hepatic metastatic burden exceeding 25% experienced a median survival time of 6.8 months, while those with a burden less than 25% had a median survival time of 10.5 months ($p<.0001$).

Aarts et al. (2021) published a systematic review and meta-analysis assessing the evidence for intra-arterial therapies in liver metastatic breast cancer. (85) A total of 26 studies representing 1266 individuals were identified, including 11 articles on RE, 10 articles on TACE, 4 articles on chemo-infusion, and 1 article comparing RE to TACE. Patient demographic information was not summarized in this publication. Pooled response rates were 49% (95% CI, 32% to 67%), 34% (95% CI, 22% to 50%), and 19% (95% CI, 14% to 25%) for RE, TACE, and chemo-infusion, respectively. Pooled median survival was 9.2 months (range, 6.1 to 35.4 months) for RE, 17.8 months (range, 4.6 to 47.0 months) for TACE, and 7.9 months (range, 7.0 to 14.2 months) for chemo-infusion. The OS rates could not be compared due to missing data at specific time points and large study heterogeneity.

Feretis et al. (2020) performed a systematic review of RE for treatment of metastatic intrahepatic breast cancer. (86) Twelve case series were included (N=452; range, 7 to 81), with a duration of follow-up ranging from 6 to 15.7 months in studies reporting follow-up duration. The age of included patients ranged from 52 to 61 years; other patient demographic information was not summarized. Overall, 52.2% of patients had breast metastases not confined to the liver. Radioembolization provided disease control in 81% of patients, and OS ranged from 3.6 to 20.9 months, with an estimated mean survival of 11.3 months.

Case Series

Ridouani et al. (2021) published the results of a retrospective study reviewing all breast cancer patients undergoing RE of liver metastases from 2011 to 2019 at a single center. (87) RE was performed with glass (66%) or resin (34%) microspheres based on operator preference. The mean age of included patients was 51 years; other patient demographic information was not summarized. Imaging response assessments were available for 60/64 patients, of which 46 (77%; 95% CI, 64% to 86%) achieved an objective response, demonstrating a 30% or greater reduction in metabolic activity. Patients with objective response had a high median dose

delivered to the tumor (167 Gy) compared to patients not achieving an objective response (54 Gy; p<.001). Eight patients developed grade 3 or higher treatment-related hepatotoxicity.

Davisson et al. (2020) retrospectively reviewed 24 patients with chemotherapy-refractory hepatic metastases from breast cancer who underwent RE from 2013 to 2018. (88) The median age of included patients was 57 years, and the majority of patients were White (54.2%). Extrahepatic metastases were reported in 18 patients, and 20 patients continued to receive concurrent chemotherapy and/or immunotherapy. Median OS was 35.4 months from first RE. Radioembolization within 6 months of hepatic metastasis diagnosis and estrogen receptor-positive status were identified as positive predictors of OS.

Metastatic Melanoma

Many studies of metastatic melanoma focus on patients with uveal melanoma, for whom the liver is the most common site of metastatic disease.

Systematic Reviews

Alexander et al. (2022) published a systematic review of RE for hepatic metastases of uveal melanoma. (89) Eleven studies representing 268 individuals were identified for review. Most studies were retrospective (n=9; 82%). The disease control rate was 67.5% and the median OS was 12.3 months. Median hepatic PFS was 5.4 months.

Rowcroft et al. (2020) planned to perform a meta-analysis of studies of patients with liver-only metastases of uveal melanoma treated with systemic therapy, isolated hepatic perfusion, hepatic artery infusion, TACE, and immunoembolization. (90) However, due to heterogeneity in available data, meta-analysis was not performed. The authors descriptively reported that 6 non-comparative retrospective cohort studies (n=150; range, 8 to 71) evaluated the use of RE, which reported median OS ranging from 9 to 24 months.

Nonrandomized Comparative Studies

Gonsalves et al. (2019) performed a prospective study of patients with liver metastases of uveal melanoma treated with RE. (91) Among patients who were treatment-naive, complete response, partial response, or stable disease was achieved in 20 of 23 patients (87.0%; 95% CI, 66.4% to 97.2%), median PFS from liver metastasis was 8.1 months (95% CI, 6.4 to 11.8 months), and median OS was 18.5 months (95% CI, 11.3 to 23.5 months). Among patients who progressed after immunoembolization, complete response, partial response, or stable disease was achieved in 14 of 24 patients (58.3%; 95% CI, 36.3% to 77.9%), median PFS from liver metastasis was 5.2 months (95% CI, 3.7 to 9.8 months), and median OS was 19.2 months (95% CI, 11.5 to 24.0 months).

Xing et al. (2017) conducted a retrospective observational study comparing outcomes for patients who had unresectable melanoma (both uveal and cutaneous) liver metastases refractory with standard chemotherapy treated with Y90 RE (n=28) or best supportive care (n=30). (92) The groups were similar at baseline in terms of Child-Pugh class, ECOG Performance Status scores, age, sex, and race. Patients treated with RE had larger tumors at

baseline (mean, 7.28 cm) than those treated with best supportive care (mean, 4.19 cm; p=.02). Median OS from diagnosis of melanoma liver metastases was longer in RE-treated subjects (19.9 months vs. 4.8 months; p<.000), as was median OS from diagnosis of the primary melanoma (119.9 months vs. 26.1 months; p<.001), respectively. Pre- and posttreatment imaging studies were available for 24 (85.7%) of 28 patients who were treated with RE. Of those, no patients had complete remission, 5 (17.9%) patients had a partial response, 9 (32.1%) patients had stable disease, and 10 (35.7%) patients had progressive disease. Two patients receiving RE had major (grade 5) clinical toxicities (ascites and hepatic encephalopathy and eventual death).

Case Series

Eldredge-Hindy et al. (2016) retrospectively evaluated outcomes for the use of Y90 RE in 71 patients with biopsy-confirmed uveal melanoma liver metastases. (93) Median time from the diagnosis of liver metastases to RE was 9.8 months (95% CI, 7.4 to 12.2 months), and 82% of patients had received prior liver-directed therapies. Sixty-one (86%) patients had computed tomography or magnetic resonance imaging evaluation of treatment response at 3 months post-RE. Of those, 5 (8%) patients had a partial response, 32 (52%) patients had stable disease, and 24 (39%) patients had disease progression. Median OS was 12.3 months (range, 1.9 to 49.3 months).

Several smaller studies published from 2009 to 2020 have reported on the use of RE in patients with hepatic metastases from melanoma. (94-97) Three included only patients with ocular melanoma, (94-96) and 2 included patients with ocular or cutaneous melanoma. (97, 98) Sample sizes ranged between 11 patients and 32 patients. Four studies excluded those with poor performance status. Median age was in the 50s for 3 studies and in the 60s for 2 studies. One article did not describe any previous treatment, and another described it incompletely. One study evaluated patients treated with RE and immune checkpoint inhibitors within a 15-month period. (98) Four studies reported tumor response data, by RECIST criteria. Among 32 patients in the study by Gonsalves et al. (2011), 1 (3%) patient had complete remission, 1 (3%) had a partial response; 18 (56%) had stable disease, and 12 (38%) had progressive disease. (94) In the study of 13 patients by Klingenstein et al. (2013), none had complete remission; 8 (62%) had a partial response; 2 (15%) had stable disease, and 3 (23%) had progressive disease. (96) Nine of 11 patients in Kennedy et al. (2009) provided response data: 1 had complete remission, 6 had a partial response, 1 had stable disease, and 1 had progressive disease. (95) In the study of 22 patients by Ruohoniemi et al. (2020), 17 patients had adequate response data: 2 had complete response, 8 had partial response, 6 had stable disease, and 1 had progressive disease. (98) Median survival in Gonsalves et al. (2011), Klingenstein et al. (2013), Ruohoniemi et al. (2020), and Kennedy et al. (2009) were 10.0 months, 19 months, 20 months, and not yet reached, respectively. (94-96, 98) Gonsalves et al. (2011) reported on 4 (12.5%) patients with grade 3 or 4 liver toxicity. (94) Klingenstein et al. (2013) observed 1 patient with marked hepatomegaly. (96) Kennedy et al. (2009) described 1 patient with a grade 3 gastric ulcer. (95) Piduru et al. (2012) (n=12) did not include any toxicity data. (97) Ruohoniemi et al. (2020) described grade 3 hepatobiliary toxicities in 3 patients within 6 months. (98)

Metastatic Pancreatic Cancer

Michl et al. (2014) reported on a case series on RE for pancreatic cancer. (99) A response was seen in 47%, with median local PFS in the liver of 3.4 months (range, 0.9 to 45.0 months). Median OS was 9.0 months (range, 0.9 to 53.0 months) and 1-year survival was 24%.

Hepatic Sarcoma

Miller et al. (2018) retrospectively reviewed 39 patients with metastatic (n=37) or primary (n=2) liver sarcoma in a multicenter study. (100) All patients had received at least 1 course of chemotherapy before receiving resin-based (n=17) or glass-based (n=22) Y90 RE. Most toxicities observed (93%) were grade 1 or 2, and the objective response rate (complete and partial responses) was 36%. Six months after treatment, 30 patients showed stable disease or response, and the median OS was 30 months (95% CI, 12 to 43 months).

Section Summary: Unresectable Intrahepatic Metastases From Other Cancers

The evidence for the use of RE to treat liver metastatic breast cancer consists of case series and systematic reviews. One meta-analysis demonstrated a pooled median survival of 9.2 months for RE and another meta-analysis reported a median survival of 9.8 months following SIRT including 7 to 81 patients, primarily patients who progressed while on chemotherapy. Radioembolization provided disease control in 81% of patients, and OS ranged from 3.6 to 20.9 months, with an estimated mean survival of 11.3 months.

The evidence for liver metastatic melanoma has demonstrated that RE has a significant tumor response; however, improvement in survival has not been demonstrated in controlled comparative studies and some serious adverse events have been reported.

The evidence for liver metastatic pancreatic cancer and hepatic sarcoma are currently insufficient to draw definitive conclusions on treatment efficacy.

Summary of Evidence

For individuals who have unresectable hepatocellular carcinoma (HCC) who receive radioembolization (RE) or RE with a liver transplant, the evidence includes primarily retrospective and prospective nonrandomized studies, with limited evidence from randomized controlled trials (RCTs). Relevant outcomes are overall survival (OS), functional outcomes, quality of life, and treatment-related morbidity. Nonrandomized studies have suggested that RE has high response rates compared with historical controls. Two small pilot RCTs have compared RE with alternative therapies for HCC, including transarterial chemoembolization and transarterial chemoembolization with drug-eluting beads. Both trials reported similar outcomes for RE compared with alternatives. Evidence from nonrandomized studies has demonstrated that RE can permit successful liver transplantation in certain patients. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have unresectable intrahepatic cholangiocarcinoma (ICC) who receive RE, the evidence includes phase 2 studies and case series. Relevant outcomes are OS, functional outcomes, quality of life, and treatment-related morbidity. Comparisons of these case series to

case series of alternative treatments have suggested that RE for primary ICC has response rates similar to those seen with standard chemotherapy. Due to high study heterogeneity, it is difficult to identify patients that are most likely to benefit from treatment. A phase 2 study of RE with chemotherapy in the first-line setting reported a response rate of 39% and a disease control rate of 98%. The efficacy of RE in the neoadjuvant setting is being evaluated in an ongoing follow-up RCT. Another phase 2 study evaluating RE with or without subsequent chemotherapy in patients without prior treatment with chemotherapy or radiation found overall response rates of 25% and 16.7% in those who received RE with and without chemotherapy, respectively; the disease control rates were 75% and 58.3% among those who received RE with and without chemotherapy, respectively. However, at this time, the evidence is not yet sufficiently robust to draw definitive conclusions about treatment efficacy. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have unresectable neuroendocrine tumors who receive RE, the evidence includes an open-label phase 2 study, retrospective reviews, and case series, some of which have compared RE with other transarterial liver-directed therapies. Relevant outcomes are OS, functional outcomes, quality of life, and treatment-related morbidity. This evidence has suggested that RE provides outcomes similar to standard therapies and historical controls for patients with neuroendocrine tumor-related symptoms or progression of the liver tumor. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have unresectable intrahepatic metastases from colorectal cancer and prior treatment failure who receive RE, the evidence includes several small- to moderate-sized RCTs, prospective trials, and retrospective studies using a variety of comparators, as well as systematic reviews of these studies. Relevant outcomes are OS, functional outcomes, quality of life, and treatment-related morbidity. While studies of patients with prior chemotherapy failure have methodologic problems and have not shown definitive superiority of RE compared with alternatives in terms of survival benefit, they tend to show greater tumor response and significantly delayed disease progression, particularly with combined use of RE and chemotherapy. For example, the Efficacy Evaluation of TheraSphere Following Failed First Line Chemotherapy in Metastatic Colorectal Cancer (EPOCH) RCT found significantly prolonged primary endpoints of progression-free survival (PFS) (hazard ratio [HR], 0.69; 95% confidence interval [CI], 0.54 to 0.88) and hepatic PFS (HR, 0.59; 95% CI, 0.46 to 0.77) with combined RE and chemotherapy in patients who had progressed on first-line chemotherapy. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have unresectable intrahepatic metastases from other cancers (e.g., breast, melanoma, pancreatic) who receive RE, the evidence includes nonrandomized studies. Relevant outcomes are OS, functional outcomes, quality of life, and treatment-related morbidity. These studies have shown significant tumor response; however, improvement in survival has not been

demonstrated in controlled comparative studies. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

Practice Guidelines and Position Statements

American College of Radiology et al.

The American College of Radiology issued a practice parameter (2021, 2024) jointly developed with the American Brachytherapy Society, the American College of Nuclear Medicine, the American Society for Radiation Oncology, the Society of Interventional Radiology, and the Society of Nuclear Medicine and Molecular Imaging addressing the use of RE for the treatment of liver malignancies with glass- or resin-based yttrium-90 microspheres. (101, 102) The guidelines provided indications and contraindications for treatment as follows:

- "Indications for both agents include but are not limited to the following:
    1. The presence of unresectable or inoperable primary or secondary liver malignancies (particularly colorectal cancer and neuroendocrine tumor metastases). The tumor burden is generally liver dominant but is not required to be exclusively within the liver.
    2. A performance status that will allow them to benefit from such therapy.
    3. A life expectancy of at least 3 months.
    4. Laboratory data that suggest the procedure can be performed safely."
- "Absolute contraindications include the following:
    1. Inability to catheterize the hepatic artery.
    2. Fulminant liver failure.
    3. Initial mapping angiography, contrast-enhanced cone beam CT (computed tomography), and/or technetium-99m macroaggregated albumin (MAA) hepatic arterial perfusion scintigraphy demonstrating clinically unacceptable nontarget deposition that cannot be ameliorated with embolization or delivery adjustment.
    4. Pretreatment hepatic arterial administration with technetium-99m MAA demonstrative of unfavorable (or unacceptable) shunt function between the liver and the pulmonary parenchyma. This shunt fraction must not be greater than acceptable limits specific to each yttrium-90 product.
    5. Acute hepatic infection.
    6. Uncorrectable coagulopathy."
- "Relative contraindications include the following:
    1. Excessive tumor burden in the liver with greater than 50% to 70% of the parenchyma replaced by tumor. In the setting of more extensive tumor burden, treatment can be considered if synthetic hepatic function is preserved.
    2. Total bilirubin greater than 2 mg/dL (in the absence of biliary obstruction or Gilbert disease), which indicates severe liver function impairment. Nonobstructive bilirubin elevations may indicate that liver metastases have caused liver impairment to the degree that risks outweigh benefits for this therapy. In contrast, patients with hepatocellular carcinoma (HCC) and elevated bilirubin may be treated with radioembolization if a segmental or subsegmental infusion can be performed.
    3. Prior radiation therapy to the liver or upper abdomen that included a significant volume of the liver (clinical judgment by the [authorized user] required).

4. Care must be employed when patients are on systemic therapies that may potentiate or may alter the impact of radioembolization and should use caution when combining therapies such as with capecitabine.
5. Pregnancy, although therapy during pregnancy may possibly be an option in extraordinary circumstances and with multidisciplinary consult and ethical considerations."

American Society of Clinical Oncology

The 2023 American Society of Clinical Oncology (ASCO) guidelines for the treatment of metastatic colorectal cancer (mCRC) makes the following relevant recommendation: (103)

- "SIRT [selective internal radiation therapy] is not routinely recommended for patients with mCRC and unilobar or bilobar metastases of the liver (Type: Evidence-based, harms outweigh benefits; Evidence quality: Low; Strength of recommendation: Weak)."

National Comprehensive Cancer Network

Primary Hepatocellular Carcinoma

The National Comprehensive Cancer Network (NCCN) guidelines (v2.2025) on the treatment of hepatocellular carcinoma indicate that the use of arterially directed therapies, including transarterial bland embolization, transarterial chemoembolization, and drug-eluting beads transarterial chemoembolization, and RE with yttrium-90 microspheres may be appropriate provided that the arterial blood supply can be isolated without excessive nontarget treatment. Patients should be considered for locoregional therapy if they are not candidates for potential curative treatments (resection, transplantation, and for small lesions, ablative strategies). RE with yttrium-90 microspheres has an increased risk of radiation-induced liver disease in patients with bilirubin levels greater than 2 mg/dL. Delivery of 205 Gy or more to the tumor may be associated with increased overall survival. A dose of greater than 400 Gy to 25% of the liver or less in patients with Child-Pugh A liver function is recommended. For anatomically limited disease, radiation segmentectomy with yttrium-90 or ablative dose stereotactic body radiation therapy should be considered. RE may be more appropriate in some patients with advanced HCC, specifically patients with segmental or lobar portal vein, rather than main portal vein thrombosis. (30)

Metastatic Neuroendocrine Tumors

The NCCN guidelines (v3.2025) on the treatment of neuroendocrine tumors recommend consideration of transarterial radioembolization (TARE) for lobar or segmental disease distribution and in patients with prior Whipple surgery or biliary tract instrumentation. (104) TARE is better tolerated than transarterial embolization/transarterial chemoembolization, but late RE-induced chronic hepatotoxicity may occur in long-term survivors, and is particularly a concern among patients undergoing bilobar RE.

Metastatic Colon Cancer

The NCCN guidelines (v4.2025) on the treatment of colon cancer provides a consensus recommendation that: "… arterially directed catheter therapy, and in particular yttrium-90 microsphere radioembolization, is an option in selected patients with chemotherapy-resistant/-

refractory disease and with predominant hepatic metastases." RE may also be considered "when hepatic metastatic disease is not optimally resectable based on insufficient remnant liver volume..." The guidelines also note that "further investigation is necessary to identify the role of radioembolization at earlier stages of disease in patients with right-sided primary origin." (105)

Metastatic Uveal Melanoma
The NCCN guidelines (v1.2025) on the treatment of uveal melanoma state the following regarding RE: "Further study is required to determine the appropriate patients for and risks and benefits of this approach." (106)

National Institute for Health and Care Excellence (NICE)
Primary Hepatobiliary Carcinoma
The July 2013 NICE interventional procedures guidance on selective internal radiation therapy for primary HCC states that the evidence for efficacy and safety is adequate for use with normal arrangements. However, "uncertainties remain about its comparative effectiveness, and clinicians are encouraged to enter eligible patients into trials comparing the procedure against other forms of treatment." (107)

In March 2021, a NICE technology appraisal guidance on selective internal radiation therapies (SIRTs) for treating HCC was published, providing specific evidence-based recommendations for the use of SIR-Spheres (Sirtex), TheraSphere (Boston Scientific), and QuiremSpheres (Quirem Medical) (last updated July 2024). (108) The guidance states that RE with SIR-Spheres or TheraSphere is recommended as an option for treating unresectable advanced HCC in adults only if "used for people with Child-Pugh grade A liver impairment when conventional transarterial therapies are inappropriate, and the company provides [the microspheres] according to the commercial arrangement." The guidance also stated that "clinical trial data for these SIRTs compared with other treatment options are limited. But, compared with sorafenib, SIRTs may have fewer and more manageable adverse effects, which can improve quality of life."

Primary Intrahepatic Cholangiocarcinoma
The October 2018 NICE interventional procedures guidance on SIRT for unresectable primary intrahepatic cholangiocarcinoma state that there are "well-recognized, serious but rare safety concerns. Evidence on its efficacy is inadequate in quantity and quality. Therefore, this procedure should only be used in the context of research." (109)

Metastatic Colon Cancer
The March 2020 NICE interventional procedures guidance on SIRT for unresectable colorectal metastases in the liver states that "in people who cannot tolerate chemotherapy or have liver metastases that are refractory to chemotherapy, there is evidence of efficacy, but this is limited, particularly for important outcomes such as quality of life. Therefore, in these people, this procedure should only be used with special arrangements for clinical governance, consent, and audit or research." (110)

Ongoing and Unpublished Clinical Trials

Some currently ongoing and unpublished trials that might influence this policy are listed in Table 7.

Table 7. Summary of Key Trials

NCT Number	Name	Planned Enrollment	Completion Date
Hepatocellular Carcinoma			
NCT06618300	Streamlined Resin Y90 Radiation Segmentectomy for Small HCC: One&Done Trial	30	Dec 2027
NCT06902246	Regorafenib and Yttrium-90 Radioembolization for Treatment of Unresectable Hepatocellular Carcinoma	28	Aug 2030 (not yet recruiting)
NCT06944483	Same-day Radioembolization for Large HCC (>5cm) With Y90 Resin Microspheres: Multicenter Prospective Registry Study	138	Dec 2029 (recruiting)
NCT06040099[a]	Phase II Single-Arm Study of Durvalumab and Bevacizumab Following Transarterial Radioembolization Using Yttrium-90 Glass Microspheres (TheraSphere™) in Unresectable Hepatocellular Carcinoma Amenable to Locoregional Therapy	100	Oct 2026 (recruiting)
NCT06166576	An Open-label, Prospective, Multi-center Clinical Trial to Evaluate the Efficacy and Safety of Ablative Radioembolization Using Yttrium-90 Glass Microspheres in Patients With Locally-advanced Hepatocellular Carcinoma	30	Nov 2027 (recruiting)
NCT05953337[a]	Radioembolization Oncology Trial Utilizing Eye90 (ROUTE 90) for the Treatment of Hepatocellular Carcinoma (HCC)	120	Oct 2025 (recruiting)
NCT04736121[a]	A Prospective, Multicenter, Open-label Single Arm Study Evaluating the Safety & Efficacy of Selective Internal Radiation Therapy Using SIR-Spheres® Y-90 Resin Microspheres on DoR & ORR in Unresectable Hepatocellular Carcinoma Patients (DOORwaY90)	100	Dec 2026 (active)
NCT04522544[a]	A Phase II Study of Immunotherapy With Durvalumab (MEDI4736) and Tremelimumab in Combination With Either Y-90 SIRT or TACE for Intermediate Stage HCC With Pick-the-winner Design	55	Dec 2026 (recruiting)
NCT05377034[a]	Multinational Phase II Trial to Compare Safety and Efficacy of SIRT (Y-90 Resin Microspheres)	176	Oct 2026 (recruiting)

	Followed by Atezolizumab Plus Bevacizumab, Vs SIRT (SIRT-Y90) Followed by Placebo in Locally Advanced HCC Patients (STRATUM)		
NCT05063565[a]	TheraSphere With Durvalumab and Tremelimumab For HCC	100	Jun 2027 (recruiting)
NCT04069468[a]	Non-Interventional Registry Study to Evaluate the Effectiveness of TheraSphere® in the Treatment of Hepatocellular Carcinoma (HCC) (PROACTIF)	1247	Dec 2024 (completed)
NCT04090645	TheraSphere & Treatment of Unresectable Primary or Unresectable Secondary Liver Cancer	187	Apr 2021 (completed)
NCT01176604	Yttrium Y 90 Glass Microspheres in Treating Patients With Unresectable Hepatocellular Carcinoma	299	Apr 2021 (completed)
NCT01556490[a]	A Phase III Clinical Trial of Intra-arterial TheraSphere® in the Treatment of Patients With Unresectable Hepatocellular Carcinoma (HCC) (STOP-HCC)	526	Apr 2022 (completed)
NCT02072356	Radiolabeled Glass Beads in Treating Patients With Liver Cancer That Cannot be Removed by Surgery	290	June 2021 (completed)
Metastatic Colorectal Cancer			
NCT05195710[a]	Preoperative Y-90 Radioembolization for Tumor Control and Future Liver Remnant Hypertrophy in Patients With Colorectal Liver Metastases	50	Mar 2026 (recruiting)
Intrahepatic Cholangiocarcinoma			
NCT06375915	Precision Medicine in Patients With Unresectable CholAngiocarcinoma: RadioEmbolization and Combined Biological Therapy (PM-CARE)	33	Jan 2026 (recruiting)
NCT02807181[a]	SIRT Followed by CIS-GEM Chemotherapy Versus CIS-GEM Chemotherapy Alone as 1st Line Treatment of Patients With Unresectable Intrahepatic Cholangiocarcinoma (SIRCCA)	89	Oct 2022 (completed)
NCT04362436[a]	A Phase II Assessment of the Safety and Efficacy of TheraSphere® Selective Internal Radiation Therapy (SIRT) in the Treatment of Metastatic (liver) neuroendocrine Tumours (NETs) (ArTisaN)	24	Sep 2024 (recruiting)
Metastatic Uveal Melanoma			

NCT06627244	Phase 2, Single Arm Study of Tebentafusp and Radioembolization in the Treatment of Metastatic Uveal Melanoma	30	Feb 2031 (recruiting)
Metastatic Breast Cancer			
NCT06860815		11	Dec 2026 (not yet recruiting)
NCT06142344	Radioembolisation and Chemotherapy in Liver Metastatic Breast Cancer Patients (HoLiBreast)	13	Jan 2026 (recruiting)

NCT: national clinical trial.

[a] Denotes industry-sponsored or cosponsored trial.

Coding

Procedure codes on Medical Policy documents are included **only** as a general reference tool for each policy. **They may not be all-inclusive.**

The presence or absence of procedure, service, supply, or device codes in a Medical Policy document has no relevance for determination of benefit coverage for members or reimbursement for providers. **Only the written coverage position in a Medical Policy should be used for such determinations.**

Benefit coverage determinations based on written Medical Policy coverage positions must include review of the member's benefit contract or Summary Plan Description (SPD) for defined coverage vs. non-coverage, benefit exclusions, and benefit limitations such as dollar or duration caps.

CPT Codes	37243, 75894, 77399, 77778, 79445
HCPCS Codes	C2616, S2095

*Current Procedural Terminology (CPT®) ©2024 American Medical Association: Chicago, IL.

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Centers for Medicare and Medicaid Services (CMS)

The information contained in this section is for informational purposes only. HCSC makes no representation as to the accuracy of this information. It is not to be used for claims adjudication for HCSC Plans.

The Centers for Medicare and Medicaid Services (CMS) does not have a national Medicare coverage position. Coverage may be subject to local carrier discretion.

A national coverage position for Medicare may have been developed since this medical policy document was written. See Medicare's National Coverage at <https://www.cms.hhs.gov>.

Policy History/Revision

Date	Description of Change
11/15/2025	Document updated. Coverage unchanged. Added references 4 and 102; others updated.

01/01/2025	Document updated with literature review. Coverage unchanged. Added references 35-37, 51-52, 78, 83, and 101; others updated/removed.
11/15/2023	Reviewed. No changes.
01/01/2023	Document updated with literature review. Coverage unchanged. New/Updated References include: 4, 14, 25-27, 33, 35-38, 40-42, 51-53, 55, 57, 75, 78, 83, 85-87, 96, 99-106.
11/01/2021	Reviewed. No changes.
04/15/2021	Policy reactivated. Document updated with literature review. Radioembolization may be considered medically necessary to treat primary hepatocellular carcinoma that is unresectable and limited to the liver. Radioembolization may be considered medically necessary in primary hepatocellular carcinoma as a bridge to liver transplantation. Radioembolization may be considered medically necessary to treat primary intrahepatic cholangiocarcinoma in patients with unresectable tumors. Radioembolization may be considered medically necessary to treat hepatic metastases from neuroendocrine tumors (carcinoid and non-carcinoid) with diffuse and symptomatic disease when systemic therapy has failed to control symptoms. Radioembolization may be considered medically necessary to treat unresectable hepatic metastases from colorectal carcinoma, melanoma (ocular or cutaneous), or breast cancer that are both progressive and diffuse, in patients with liver-dominant disease who are refractory to chemotherapy or are not candidates for chemotherapy or other systemic therapies. Radioembolization is considered experimental, investigational and/or unproven for all other hepatic metastases except as noted above. Radioembolization is considered experimental, investigational and/or unproven for all other indications not described above.
10/02/2016	Document became inactive.
05/01/2015	Document updated with literature review. The following was added to the experimental, investigational and/or unproven coverage statement: “Including, but not limited to primary intrahepatic cholangiocarcinoma”.
03/01/2013	Document updated with literature review. Coverage unchanged. Title changed from “Selective Internal Radiation Therapy (Radioembolization) for Primary and Metastatic Tumors of the Liver”.
08/01/2010	Document updated with literature review. The following was added: SIRT (radioembolization) may be considered medically necessary as palliative treatment for individuals with (1) neuroendocrine tumors (e.g. carcinoid tumors, pancreatic islet cell tumors, parathyroid, pituitary angiomas) with hepatic metastases, when systemic therapy has failed to control symptoms such as carcinoid syndrome (e.g. debilitating flushing, wheezing, and diarrhea); or (2) symptoms from non-carcinoid neuroendocrine tumors with hepatic metastases (e.g. hypoglycemia, severe diabetes, Zollinger-Ellison Syndrome). In addition the following was added: SIRT for primary and

	metastatic tumors of the liver not addressed above, are considered experimental, investigational and unproven.
02/01/2008	New medical document