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Research Article

Packing density and long-term occlusion after transcatheter vessel embolization with soft, bare-platinum detachable coils

James Vogler IV, Mark Gemender, Dmitri Samoilov

Department of Interventional Radiology, Eastern Virginia Medical School, Norfolk, Virginia, United States.

***Corresponding author:**
James Vogler IV,
Department of Interventional Radiology, Eastern Virginia Medical School, Norfolk, Virginia 23501, United States.

jbvogler4@gmail.com

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ABSTRACT

Objective: The objective of this study was to examine packing density and long-term recanalization rates after embolization with soft, bare-platinum ruby coils in the gastroduodenal artery (GDA).

Materials and Methods: Retrospective case review of patients with hepatic malignancy who underwent coil occlusion of the GDA for radioembolization or hepatic arterial infusion chemotherapy between November 2013 and July 2018. Data on patient demographics, GDA diameter, length of coil pack, and distance between GDA origin and most proximal coil were collected. Packing density was calculated as the ratio between the volume of inserted coils and the volume of the vessel area that were filled with coil. The primary outcome was the rate of GDA recanalization, determined by review of hepatic arteriograms at follow-up.

Results: Long-term occlusion free of recanalization was observed in 97.8% (88/90) of patients over a median follow-up time of 13.4 ± 11.3 months. Median vessel packing density was 55% (interquartile range 41–71) and procedural technical success was achieved in 100% (90/90) of patients. Of the 90 patients (72 men; mean age 63.8 ± 7.5 years), mean GDA diameter was 4.0 ± 0.8 mm and the proximal coil distance from GDA origin was 8.6 ± 3.0 mm. Mean coil pack length was 21.2 ± 7.6 mm. Recanalization occurred in 2.2% (2/90) of patients. No increase in recanalization rates with distal coil placement was observed.

Conclusions: The study demonstrates high levels of technical success and low rates of recanalization (2.2%) when high packing densities (55%) are achieved using soft, bare-platinum ruby coils. The rate of recanalization at follow-up compares favorably to previously reported literature.

Keywords: Bare-metal coils, Peripheral embolization, Vessel sacrifice

INTRODUCTION

Current coil embolization technologies include fibered, hydrogel-coated, and bare-metal coils. The former rely on a dense network of synthetic fibers or an expansile hydrogel polymer, whereas bare-metal coils, such as the Ruby Coil (Penumbra, Alameda, CA, USA), rely on coil pack density for intravascular mechanical occlusion. The importance of coil pack density on long-term durability of vessel occlusion was first demonstrated in the treatment of cerebral aneurysms. Several studies demonstrated a higher coil packing density and lower aneurysm recurrence rate when utilizing soft, bare-platinum coils compared to fibered or bioactively coated coils.[1-4] In the peripheral vasculature, packing density has also been shown to be an important predictor for recanalization of visceral aneurysms. Yasumoto *et al*. correlated coil compaction and packing density in visceral artery aneurysms and reported no compaction or recanalization over a mean of 37 months in 46 aneurysms with a packing density ≥24%.[5] Similarly, Wojtaszek *et al*. reported no sac reperfusion at mid-term follow-up in splenic artery aneurysms with packing densities ≥29%.[6]

The previous studies report long-term recanalization rates of up to 20.4% with conventional fibered coils and limited long-term data exist describing long-term durability with other technologies.[7] The impact of coil packing density on long-term durability of visceral vessel embolization has yet to be reported. The objective of this study is to apply the concept of packing density to the setting of vessel sacrifice and to report long-term recanalization rates after embolization with soft, bare-platinum Ruby Coils in the gastroduodenal artery (GDA).

MATERIALS AND METHODS

Patient selection criteria

Institutional review board approval was obtained from the home author's institution. Consecutive patients that underwent Ruby Coil occlusion of the GDA for radioembolization (Y90) or hepatic arterial infusion chemotherapy (HAIC) between November 2013 and July 2018 were retrospectively reviewed. All cases were performed by a single interventional radiology with >10 years of experience at a single institution. Inclusion criteria for this study included treatment with Ruby coils for GDA embolization and availability of one subsequent angiogram on a minimum 30 days follow-up. Based on this inclusion criterion, 90 patients were identified. Collected background demographic data included age, gender, presenting diagnosis, and initial therapy.

Image analysis

Digital subtraction angiographic images were retrospectively reviewed by the senior author. The following variables were collected: GDA diameter (defined as width at most proximal coil), mean distance from GDA origin to most proximal coil (determined by length of a straight line, parallel to the GDA long axis, and between the GDA origin and the most proximal coil), length of coil pack, and presence of persistent flow.

Angiography and embolization technique

All patients that underwent radioembolization treatment underwent a preparatory hepatic angiogram to delineate non-conventional vascular anatomy, embolization of the GDA and, if necessary embolization of additional hepaticoenteric collaterals. For patients that underwent HAIC, this was performed on the day of procedure.

Regardless of therapy type, GDA embolization technique was identical. A 5F Simmons 1 catheter (Merit, Salt Lake City, UT, USA) was reformed in the distal abdominal aorta using the Cope string technique and used to access the celiac trunk. Through this base catheter, a 2.6F Lantern microcatheter (Penumbra, Alameda, CA, USA) was coaxially advanced into the proximal GDA and soft or standard, bare-platinum 0.020″ Ruby coils were placed. Coils were packed densely within the GDA. The Lantern microcatheter was withdrawn into common hepatic artery and post coil embolization angiography immediately performed. The presence of complete vascular occlusion or persistent flow was recorded at that time.

For patient undergoing radioembolization, the same procedure was used to perform diagnostic angiography of the hepatic vasculature in multiple obliques before radioembolic administration. The presence or absence of recanalization was documented at this time. In instances of recanalization, placement of additional Ruby coils proximal to the coil mass was attempted. If not feasible, the microcatheter was positioned distal to the GDA origin or the dose fractionated, depending on clinical scenario. The patients that underwent HAIC received a follow-up angiogram at 1 month to document if recanalization was present. In many cases, patients that underwent HAIC or radioembolization received multiple treatments. In this case, the presence or absence of recanalization was based on the final angiogram.

Packing density calculation

Packing density was calculated as the ratio between the volume of inserted coils and the volume of the vessel area that were filled with coil. The volume of the inserted coils was calculated using the formula for the volume of a cylinder (Volume= π* radius^2 * length), with Ruby Coil radius equal to.010. The volume of the vessel was calculated using volume of a cylinder. The vessel radius and length of coil landing zone were measured by angiography. In some cases, a single strand or loop was subtracted to reflect a more accurate packing density.

Statistical analysis

All statistical analyses were conducted using the Minitab 18 software package. Baseline patient demographic information is expressed with standard descriptive statistics. Procedural outcome data are expressed as a frequency, mean or median ± standard deviation, or interquartile range (IQR), respectively, where applicable.

RESULTS

The study population consisted of 90 patients (72 men; mean age 63.8 ± 7.5 years) with diagnoses of hepatocellular carcinoma (78/90, 87%), metastatic disease (11/90, 12%), and cholangiocarcinoma (1/90, 1%). The patient demographic criteria are summarized in Table 1. Mean platelet count was 139,000 ± 82,000/ml and mean INR was 1.1 ± 0.1.

About 100% (90/90) procedural technical success was achieved. In all cases, the coil pack distance from origin was adequate and further coil placement without migration into hepatic vasculature was deemed unsafe. Data on the number of coils and coil sizes used were available in 57% (51/90) patients. Coils size ranges from 3 × 5 mm to 8 × 60 mm. The mean number of coils was 3.0 ± 1.5. Mean GDA diameter was 4.0 ± 0.8 mm and the proximal coil distance from GDA origin was 8.6 ± 3.0 mm. No increase in recanalization rates with distal coil placement was observed. Mean coil pack length was 21.2 ± 7.6 mm. Median packing was density 55% (IQR, 41-71) [Figure 1]. There were eight cases (8.8%) of persistent flow at post-procedure. Technical parameters are reported in Table 2.

On follow-up angiogram (mean duration of follow-up was 13.4 ± 11.3 months), 2.2% (2/90) of patients demonstrated recanalization. Recanalization was identified on days 20 and 24 in these two patients. None of these patients underwent additional embolization or had variant GDA anatomy. Due to the small number of recanalizations, no statistically comparison baseline between those who recanalized and those who did not was performed. However, one of the patients who recanalized had a packing density of 16% and had persistent flow. The other patient who recanalized did not have available data on packing density, but was on anticoagulation (coumadin) due to end-stage renal disease (ESRD) on dialysis.

DISCUSSION

This study provides long-term recanalization rates after coil embolization with soft, bare-platinum detachable coils and estimates packing density with vessel sacrifice. The findings demonstrate that with high packing density (55%), a very low rate of GDA recanalization (2.2%) over long-term follow-up is observed. While embolization of the GDA is no longer commonplace in the setting of transarterial radioembolization, these findings may potentially have broader implications in other vascular vessel beds commonly embolized with coils.

Short-term durability of embolization has been reported in several studies using fibered coils in the GDA or other peripheral vessels, with reported recanalization rates ranging from 0% to 20% in patients at approximately 1–4 weeks post-embolization.[7-14] The 2.2% recanalization rate at 13.4 months follow-up observed in this study is in the low range compared to these studies; however, limited data exist on longer-term durability of coil embolization. Enriquez *et al.* reported much higher GDA recanalization rates of 20.4% (29/142) with fibered coils over a mean follow-up period of 101 days (range, 7–560 days).[7] In this study, the authors used fibered coils (Tornado or VortX) and analyzed technical factors influencing recanalization. Out of all factors analyzed, the only factor found to be statistically significant was the coil distance from GDA origin. Their multivariate analysis revealed that the further the coil mass was from the GDA origin, the more likely the vessel would recanalize. The

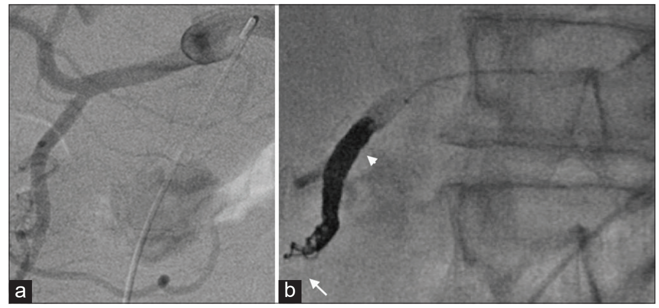

Figure 1: 79F undergoing 90Y radioembolization for hepatocellular carcinoma. (a) DSA using Simmons 1 catheter demonstrating conventional celiac anatomy. (b) Post-embolization angiography with Lantern microcatheter (Penumbra) demonstrating no persistent flow (arrow) and dense coil packing (arrowhead).

Table 1: Baseline patient characteristics.

Characteristic	Total (%)
n	90
Age	
Mean (±SD)	63.8 (7.5)
Gender	
Male	72 (80.0)
Tumor type	
HCC	78 (86.7)
Metastatic disease	11 (12.2)
Cholangiocarcinoma	1 (1.1)
Procedure type	
90Y Radioembolization	86 (95.6)
Total	90

Table 2: Technical factors of recanalization.

	***n*=90**
GDA diameter (mm)	
Mean (SD)	4.0 (0.8)
Distance from origin (mm)	
Mean (SD)	8.6 (3.0)
Length of coil pack (mm)	
Mean (SD)	24.3 (8.2)
Length of coil pack minus tail (mm)	
Mean (SD)	21.4 (7.6)
Median packing density (%)	
Median (IQR)	55 (41–71)
Persistent flow (*n*)	
Presence	8

distance was 9.6 versus 12.6 mm ($P = 0.01$) in the persistent occlusion versus recanalization groups, respectively.[7] We hypothesize that higher intravascular pressure proximal to the fibered coils placed distally, and the lack of dense packing can break the thrombus dependent occlusion over time.

In our data, the distance of the proximal coil from the GDA origin did not appear to be an indicator of recanalization. Mean proximal coil distance from GDA origin was 8.6 mm, well below 12.6 mm, the only published risk factor for recanalization.[7] Furthermore, in this study, no recanalizations were observed in 20 patients with a coil distance from origin equal to or >12.6 mm.

A recent animal model study comparing embolization with hydrogel-coated coils or fibered coils in the renal and internal iliac arteries showed high thrombus dependence with both fibered and hydrogel coated coils. With fibered coils, approximately 69% of the resulting vessel cross-section consists of thrombus, and 31% is coil and fiber. With hydrogel coated coils, 42% of the vessel cross section consists of thrombus and 58% consists of coil and hydrogel.[15] Importantly, these figures are vessel cross-sectional areas, not vessel packing densities as reported with in this study. Ruby coils used in this analysis are characterized by their softness, volume (0.020" compared to 0.012" conventional fibered coils) and long lengths. These characteristics, as well as their bare-platinum design on a detachable platform help to achieve high, consistent packing density and complete cross-sectional occlusion within the vessel [Figure 2].

Figure 2: Lateral and vessel cross-sectional images in equal size glass vessels of fibered, hydrogel coated, and soft bare-platinum Ruby Coils. Top: Fibered coil; Middle; hydrogel coil Bottom; soft, bare-platinum ruby coil. Ruby coils have thicker and softer coil loops that densely pack creating a mechanical occlusion with less reliance on thrombus formation. Images supplied by Penumbra Inc.

The ability to achieve complete cross-sectional vessel occlusion and high packing densities with less reliance on thrombus formation is suggested by the favorable rate of persistent flow in this study of 8.8% compared to 16% with fibered coils, as published by Enriquez *et al.*[7] The lower rate of persistent flow with soft, large volume, and detachable coils could offer lower recanalization rates and enhanced long-term durability of occlusion compared to traditional coil technology. Furthermore, in one of the patients recanalized in our study, packing density was low (16%). The other patient who recanalized did not have available data on packing density; however, the patient was on anticoagulation due to ESRD, suggesting that chronic hypocoagulability may also contribute to recanalization. Further investigation is needed to confirm the association between recanalization and packing density after vessel sacrifice.

Limitations of this study include the retrospective design and the small number of recanalized patients that precluded identification of patient factors that might predict recanalization. In addition, packing density was unable to be calculated in patients where multiple vessels were embolized, due to lack of documentation regarding which coils were deployed within the GDA.

Further implications of the data could address other high flow vascular beds, for example, pulmonary arteriovenous malformations (PAVMS). For PAVMS treated with bare-metal or fibered coils, long-term recanalization rates range from 11.7% to 49%.[16-18] As described in these papers, recanalization with fibered coils can be higher in these distal, high flow, and high pressure systems.

Based on our experience, we hypothesize that achieving high packing density and mechanically occluding the vessel may help to improve recanalization rates throughout the peripheral vasculature where recanalization has been reported to be fairly common. Further studies are necessary to further examine this hypothesis in other high flow and high pressure vascular beds.

CONCLUSIONS

This study demonstrates a high level of technical success and very low rate of GDA recanalization (2.2%) and high packing density (55%) when using soft, bare-platinum detachable coils. The findings compare favorably to the reported long-term recanalization rates when using fibered coils. Unlike previously reported data with fibered coils, in this study distal coil placement was not a predictor of recanalization. Future studies are needed to examine whether similarly low recanalization rates and high packing densities can be demonstrated in other high-flow vessels.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Mascitelli JR, Patel AB, Polykarpou MF, Patel AA, Moyle H. Analysis of early angiographic outcome using unique large diameter coils in comparison with standard coils in the embolization of cerebral aneurysms: A retrospective review. J Neurointerv Surg 2015;7:126-30.
2. Mascitelli JR, Polykarpou MF, Patel AA, Kamath AA, Moyle H, Patel AB. Initial experience with Penumbra coil 400 versus standard coils in embolization of cerebral aneurysms: A retrospective review. J Neurointerv Surg 2012;5:573-6.
3. Milburn J, Pansara AL, Vidal G, Martinez RC. Initial experience using the Penumbra coil 400: Comparison of aneurysm packing, cost effectiveness, and coil efficiency. J Neurointerv Surg 2014;6:121-4.
4. Kaesmacher J, Muller-Leisse C, Huber T, Boeckh-Behrens T, Haller B, Shiban E, *et al*. Volume versus standard coils in the treatment of intracranial aneurysms. J Neurointerv Surg 2016;8:1034-40.
5. Yasumoto T, Osuga K, Yamamoto H, Ono Y, Masada M, Mikami K, *et al*. Long-term outcomes of coil packing for visceral aneurysms: Correlation between packing density and incidence of coil compaction or recanalization. J Vasc Interv Radiol 2013;24:1798-807.
6. Wojtaszek M, Lamparski K, Wnuk E, Ostrowski T, Maciąg R, Rix T, *et al*. Selective occlusion of splenic artery aneurysms with the coil packing technique: The impact of packing density on aneurysm reperfusion correlated between contrast-enhanced MR angiography and digital subtraction angiography. Radiol Med 2019;124:450-9.
7. Enriquez J, Javadi S, Murthy R, Ensor J Jr., Mahvash A, Abdelsalam ME, *et al*. Gastroduodenal artery recanalization after transcatheter fibered coil embolization for prevention of hepaticoenteric flow: Incidence and predisposing technical factors in 142 patients. Acta Radiol 2013;54:790-4.
8. Pech M, Kraetsch A, Wieners G, Redlich U, Gaffke G, Ricke J, *et al*. Embolization of the gastroduodenal artery before selective internal radiotherapy: A prospectively randomized trial comparing platinum-fibered microcoils with the Amplatzer vascular plug II. Cardiovasc Intervent Radiol 2009;32:455-61.
9. Bulla K, Hubich S, Pech M, Lowenthal D, Ricke J, Dudeck O. Superiority of proximal embolization of the gastroduodenal artery with the Amplatzer vascular plug 4 before yttrium-90 radioembolization: A retrospective comparison with coils in 134 patients. Cardiovasc Intervent Radiol 2014;37:396-404.
10. Dudeck O, Bulla K, Wieners G, Ruehl R, Ulrich G, Amthauer H, *et al*. Embolization of the gastroduodenal artery before selective internal radiotherapy: A prospectively randomized trial comparing standard pushable coils with fibered interlock detachable coils. Cardiovasc Intervent Radiol 2011;34:74-80.
11. Maleux G, Deroose C, Fieuws S, Van Cutsem E, Heye S, Bosmans H, *et al*. Prospective comparison of hydrogel-coated microcoils versus fibered platinum microcoils in the prophylactic embolization of the gastroduodenal artery before yttrium-90 radioembolization. J Vasc Intervent Radiol 2013;24:797-803.
12. Abdelmaksoud MH, Hwang GL, Louie JD, Kothary N, Hofmann LV, Kuo WT, *et al*. Development of new hepaticoenteric collateral pathways after hepatic arterial skeletonization in preparation for yttrium-90 radioembolization. J Vasc Intervent Radiol 2010;21:1385-95.
13. McWilliams JP, Kee ST, Loh CT, Lee EW, Liu DM. Prophylactic embolization of the cystic artery before radioembolization: Feasibility, safety, and outcomes. Cardiovasc Intervent Radiol 2011;34:786-92.
14. Petroziello MF, McCann JW, Gonsalves CF, Eschelman DJ, Anne PR, Sato T, *et al*. Side-branch embolization before 90Y radioembolization: Rate of recanalization and new collateral development. AJR Am J Roentgenol 2011;197:W169-74.
15. Fohlen A, Namur J, Ghegediban H, Laurent A, Wassef M, Pelage JP. Peripheral embolization using hydrogel-coated coils versus fibered coils: Short-term results in an animal model. Cardiovasc Intervent Radiol 2018;41:305-12.
16. Andersen PE, Duvnjak S, Gerke O, Kjeldsen AD. Long-term single-center retrospective follow-up after embolization of pulmonary arteriovenous malformations treated over a 20-year period: Frequency of re-canalization with various embolization materials and clinical outcome. Cardiovasc Intervent Radiol 2019;42:1102-9.
17. Mager JJ, Overtoom TT, Blauw H, Lammers JW, Westermann CJ. Embolotherapy of pulmonary arteriovenous malformations: Long-term results in 112 patients. J Vasc Intervent Radiol 2004;15:451-6.
18. Shimohira M, Kawai T, Hashizume T, Ohta K, Nakagawa M, Ozawa Y, *et al*. Reperfusion rates of pulmonary arteriovenous malformations after coil embolization: Evaluation with time-resolved MR angiography or pulmonary angiography. J Vasc Intervent Radiol 2015;26:856-64.

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