Portal Vein Embolization: Techniques

David C. Madoff, M.D.
Professor of Radiology
Vice Chairman for Academic Affairs
@dcmadoff
David Madoff, M.D.

- No relevant financial relationship reported
Portal Vein Embolization (PVE)

Redirects portal blood flow to FLR:
- Initiates **HYPERTROPHY** of non-embolized segments
- ↓ perioperative complications
- ↑ potential surgical candidates with **MARGINAL** anticipated FLR volumes
- Achieve similar survival rates to surgical patients not requiring PVE

Makuuchi, *Surgery* 1990
de Baere, *Radiology* 1993
Madoff, *J Vasc Interv Radiol* 2005
May, *J Vasc Interv Radiol* 2013
Various Techniques Described for PVE

- Transiliocolic
- Transhepatic contralateral
- Transhepatic ipsilateral
- Transjugular
- Transarterial
- Transsplenic
- Transsinusoidal
- Reversible
- Combination approaches – TAE/PVE; PVE/HVE; PVE + stem cells

May, J Vasc Interv Radiol 2013
Transiliocolic Approach

Original PVE description

Laparotomy w/pararectus skin incision to RLQ (~10 cm in length)

Terminal portion of ileum extracted from incision

One branch of ileocolic vein

6F sheath fixed in place →
5.2F catheter inserted into main PV

Pre-PVE

Post-PVE
Transhepatic Contralateral Approach

1st Percutaneous Approach
Access via Remnant Liver

**Advantage**
Direct access to right PV branches

**Disadvantages**
Potential FLR injury
LPV thrombosis
Segment 4 catheterization may be difficult

RPVE with n-butyl cyanoacrylate

---

de Baere, *Radiology* 1993
Transhepatic Contralateral Approach

Arterial pseudoaneurysm
Pancreatic duodenectomy *without right hepatectomy 2 months after PVE*

Courtesy of Dr. Y. Kodama, Sapporo, Japan
Transhepatic Ipsilateral Approach

Access via Diseased Liver

**Advantages:**
Avoids FLR injury
Segment 4 easily accessible

**Disadvantages:**
May need to complete procedure through previously occluded PVs
Difficult access with large tumors??

Right PVE with Particles & Coils

Nagino, *Radiology* 1996
Madoff, *Radiology* 2003
Transhepatic Ipsilateral Approach

Subcapsular hematoma – evacuated at time of successful resection

Madoff, Radiology 2003
Transhepatic Ipsilateral Approach

Arterial pseudoaneurysm

*Extended right hepatectomy performed 27 days after PVE*

Courtesy of Dr. Y. Kodama, Sapporo, Japan
Ipsilateral vs. Contralateral Approach

_Ipsilateral_ Now Favored

- Most prudent to _avoid access-related complications within FLR_

- Especially beneficial if segment 4 is embolized
  - With experience, acute angles encountered are easily navigated with reverse curve catheters & considered of little importance & consequence

- If tumor burden precludes safe access route to RPV branches or if fast polymerizing liquid embolics (e.g., NBCA) utilized, then contralateral approach is reasonable alternative
Transjugular Approach

RPVE with n-butyl cyanoacrylate

Perarnau, *Hepatogastroenterology* 2003
Courtesy of James Caridi, M.D., New Orleans, LA
Transarterial Approach

Hepatic sinusoidal anatomy

Arteries to left & middle hepatic lobes infused w/ ethiodol:ethanol (3:1) until 3\textsuperscript{rd}/4\textsuperscript{th} order PVs seen

Madoff, J Vasc Interv Radiol 2007
Transarterial Approach

Massive Hypertrophy of right & right middle lobes

Madoff, J Vasc Interv Radiol 2007
Transarterial Approach

13cm solitary right HCC w/HCV cirrhosis

“Technically resectable” but FLR 27%

↓

Selective cTACE
100mg Cisplatin
50mg Doxorubicin
10mg Mitomycin C
10 ml ethiodized oil
Transarterial Approach

One month after cTACE → RPVE performed

*Right posterior sector portal vein occluded pre-PVE*
Transarterial Approach

Can transarterial therapy alone can lead to sufficient hypertrophy making PVE unnecessary?
Transarterial Approach

*Planned* Sequential Transarterial Embolization & PVE

Contrast-enhanced CT before TAE

72-year-old man with HCC (9 cm) with non-alcoholic steatohepatitis (NASH)

FLR/TELV = 37%
Transarterial Approach

**Planned** Sequential Transarterial Embolization & PVE

Pre-embolization

Post-embolization

Bland embolization with 100 µm microspheres
1 month later, mass largely necrotic – significant hypertrophy seen  
**FLR/TELV = 51%**
Transarterial Approach

**Planned** Sequential Transarterial Embolization & PVE

72-year-old man with HCC (9 cm) with non-alcoholic steatohepatitis (NASH)

Pre-TAE

1 month post-TAE

$\downarrow$

Substantial hypertrophy – DH: 14%

NO PVE $\rightarrow$ Uneventful Right Hepatectomy
Transarterial Approach
Arterial Embolization to Increase Resection – *Prospective*

- 13 patients underwent preoperative arterial embolization of right liver
- 4 – 15 coils
- CT volumetric assessment
  - Right liver → 2-33% ↓ (m, 10%)
  - Left liver → 11-68% ↑(m, 37%)
- 9 patients had extended right hepatectomy 27-75d (m, 44d)
- No major complications

Right arterial coil embolization
↓
Left liver hypertrophy allows for extended right hepatectomy in initially unresectable hilar cholangiocarcinoma

Vogl, *Radiology* 1998
Transarterial Approach
Arterial Embolization vs. PVE – *Prospective Randomized*

- 50 patients with hilar cholangiocarcinoma from 2003 – 2006
- Planned extended right hepatectomy
  - R-TAE with PVA particles & coils ($n=25$)
  - R-PVE with PVA particles ($n=25$)
  - CT volumetry performed before & approximately 3 weeks later
- Results
  - R-TAE – FLR $\uparrow$ 40 mL ($P < .01$)
  - R-PVE – FLR $\uparrow$ 110 mL ($P < .01$)
  - *FLR growth after PVE significantly greater than after TAE* ($P = .004$)
  - Minor complications: R-TAE: liver abscess ($n=2$); R-PVE: subcapsular seroma ($n=1$)

*Compared with TAE, PVE was significantly superior regarding FLR hypertrophy*
Transsplenic Approach

Gastroesophageal variceal bleeding & HCC in a 47-year-old man

Not used in routine clinical practice

↑↑ vascularity of spleen → ↑ risk of bleeding
Transsplenic Approach

Gastroesophageal variceal bleeding & HCC in a 47-year-old man

11 patients – RPVE (n=10); LPVE (n=1)
After PVE, transsplenic access embolized w/coils & nBCA
No procedure-related complications except abdominal pain during or after PVE

Zhu, J Vasc Interv Radiol 2013
Han, Korean Congress of Radiology Abstract Book 2015
Transsinusoidal Approach

**Feasibility in 8 swine**
Indirect portography – cranial mesenteric art.
Embolic – ethylene vinyl alcohol copolymer
Low viscosity – deep penetration

*Injected via microcatheter wedged in HV & advanced through sinusoids into PVs*

Successful in 5/8 (63%)
No periprocedural adverse events
Hypertrophy not assessed

Smits, *Cardiovasc Intervent Radiol* 2012
“Reversible” Approach

Pre-clinical study – 9 monkeys
PVE with Curaspon powder – distal venous obstruction?
Liver segment volumes determined by CT: Pre-, 1-mo & 1-yr after PVE
Significant hepatocyte proliferation & hypertrophy in non-embolized liver
Hypertrophy not transient

“Reversible” PVE efficiently induces liver regeneration & avoids long-term liver scarring caused by more permanent embolics

Lainas, J Hepatol 2008
Combination Approaches
Sequential Transarterial Embolization & PVE

56-year-old man with HCV, HCC (12cm) & cirrhosis
FLR/TELV = 30%

Arterial Phase

Portal Phase

May, J Vasc Interv Radiol 2013
Combination Approaches
Sequential Transarterial Embolization & PVE

Bland embolization with 40 µm microspheres

Pre-embolization

Post-embolization
Combination Approaches
Sequential Transarterial Embolization & PVE

1 month later, ipsilateral RPVE with microspheres & coils
Combination Approaches
Sequential Transarterial Embolization & PVE

Segments 1/2/3/4 = 30%

Segments 1/2/3/4 = 54%

$DH = 24\%$

Patient underwent successful right hepatectomy
Combination Approaches
Sequential Transarterial Embolization & PVE

% FLR Volume

Pre-Embolization  Post-Embolization

TACE + PVE n=18
PVE n=18

P = .013

PVE 3 weeks after TACE
83% complete pathological response

Improved 5-yr DFS
19% vs. 31%
P = .041

Ogata, Br J Surg 2006
Combination Approaches
Sequential Transarterial Embolization & PVE

1997 – 2008, 135 patients with HCC
Sequential TACE and PVE (n = 71) vs. PVE alone (n = 64)

Baseline patient & tumor characteristics similar in both groups

PVE performed mean 1.2 months after TACE

CT liver volumetry performed before & 2 weeks after PVE
Mean \( \uparrow \) in \% FLR volume higher in
**TACE & PVE group (7.3\%)** than **PVE-only group (5.8\%)** \((p = 0.035)\)
Combination Approaches
Sequential Transarterial Embolization & PVE

Overall ($p = 0.028$) & disease-free ($p = 0.001$) survival rates significantly higher in TACE & PVE group than in PVE-only group

Yoo, Ann Surg Oncol 2011
Combination Approaches
Sequential PVE & Hepatic Vein Embolization (HVE)

*PVE does not always induce sufficient liver regeneration*

HVE – 12 pts after PVE
RHV embolized with coils after insertion of IVC filter or vascular plugs

LFTs w/o significant change
Cirrhotic livers w/↓ regeneration rates following HVE after PVE
Wrong HV trunk in 1 patient

**Conclusion**
Sequential PVE & HVE safe & effective for contralateral hypertrophy than PVE alone

*FLR/TLV*
35% ± 2% before PVE
40% ± 1% 1 to 2 wks after PVE
44% ± 1% 2 wks after HVE
66% ± 6% 1 wk after hepatectomy

Combination Approaches
Liver Venous Deprivation (LVD) Technique

**Single session PVE & HVE for liver regeneration before hepatectomy**

7 pts: Liver Metastases (n=2), HCC (n=1), ICC (n=3) & Klatskin Tumor (n=1)

**RESULTS**
Mean of 3 days transaminases ↑

Mean 23d after LVD
FLR ↑: 28% → 41%

During 1st 7d, venous-deprived liver volume ↑ (+13.4 %) whereas it strongly ↓ (-21.3 %) at 3 – 4 wks

**HISTOLOGY**
Sinusoidal dilatation, hepatocyte necrosis & atrophy in all patients

Technical success 100 % & no complications before surgery

Resection performed in 6/7 pts

**Conclusions**
LVD feasible, well tolerated & provides fast FLR hypertrophy &

LVD needs to be further evaluated & compared to PVE

Combination Approaches
PVE with Addition of Stem Cells

- Bone Marrow Stem Cells (BMSCs) are source of hepatic stem cells
- BMSCs participate & accelerate hepatic regeneration
- Portal BMSCs administration + PVE vs. PVE alone
  Amount of hypertrophy: 77% vs. 39% (P=.039)

Retrospective study of extended right hepatectomy
  - 40 patients – median 28 month followup
    - No PVE = 18; PVE = 11; PVE + SC = 11
    - PVE + SCs (138.66 ml ± 66.29)
    - PVE alone (62.95 ml ± 40.03)
  - ↓ major complications, ↑ FLR, ↑ overall survival

Fürst, Radiology 2007
Esch, Ann Surg 2012
Conclusion

- PVE is an important tool in the liver cancer treatment paradigm
  - Hypertrophy FLR before hepatic resection

- Many different techniques used over the years
  - Transiliocolic – original description
  - Most common percutaneous approaches – ipsilateral & contralateral

- Newer techniques & strategies being developed
  - Combination therapy
  - Transarterial
  - Transsplanic
  - Transsinusoidal
  - “Reversible”