Caval interruption: methods and indications

Venous thromboembolism is a significant cause of morbidity and mortality worldwide. Anticoagulation is the preferred treatment, but is not feasible in some patients. Caval interruption is the treatment of choice for prevention of recurrent pulmonary embolism. This article looks at the development of caval interruption.

Venous thromboembolism remains a significant cause of mortality and morbidity worldwide despite advances in both medical and surgical interventions. The annual incidence of diagnosed venous thromboembolism is approximately 1–2 events per 1000 population (Kearon, 2001), with a sharp increase in incidence over 60 years of age (Silverstein et al, 1998). The potential consequences are serious, with the mortality from untreated pulmonary embolism approaching 25–30% (Carson et al, 1992). Management options include control of predisposing factors, anticoagulation and caval interruption. None of these therapies, however, afford complete protection from venous thromboembolism and its complications. This overview focuses on the concept of caval interruption and its development since its inception (*Table 1*).

Caval ligation and clips

Trousseau first proposed the concept of caval interruption in 1865 (Trousseau, 1868) but the first successful ligation of the inferior vena cava was not reported until 1893 by Bottini. In the 1930s Homans proposed bilateral common femoral vein ligation as a preventative measure for pulmonary embolism (Homans, 1934). Shortly thereafter, case series were reported with patients undergoing inferior vena cava ligation for thromboembolism (Ochsner and DeBakey, 1943; O'Neil, 1945). Caval ligation remained the procedure of choice for recurrent thromboembolism for the following decade. There were obvious problems with this procedure, however, including acute haemodynamic consequences. Impaired cardiac output was reported as a result of inadequate venous return (Miller and Staats, 1988) and mortality rates after ligation were reported as between 19 and 39% (Nasbeth and Morgan, 1965; Amador et al, 1968).

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This led to the development of external clipping of inferior vena cava by Moretz and colleagues in 1959. The purpose of these clips was to create a slit-like inferior vena cava to reduce the number of large emboli entering the pulmonary circulation in thromboembolic disease. However, this was still associated with leg oedema, stasis dermatitis, leg ulcers and venous claudication (Mansour et al, 1985).

Initial development of inferior vena cava filters

Inferior vena cava ligation and clip insertion required a laparotomy under general anaesthesia with its attendant risks. In 1969 Mobin-Uddin and colleagues therefore proposed using transvenous filter devices for caval interruption to minimize mortality and morbidity. They developed a filter that could be placed by venotomy. The filter consisted of a Silastic membrane connected to six stainless steel spokes, anchoring it in the vena cava. However, it was repeatedly reported that the filter was associated with proximal migration (including into the pulmonary artery) and proximal inferior vena cava thrombosis. It was removed from the market in 1977 (Adelson et al, 1980). Over the last 30 years, a number of different types of inferior vena cava filter have been released onto the market. This review considers these developments, and the purported advantages of each model.

Inferior vena cava filter types

Greenfield filter

The Greenfield filter was launched in 1972 shortly after the Mobin-Uddin umbrella (Greenfield et al, 1973) and remains in use today. With 30 years of follow-up data it is the benchmark against which caval filters are compared. The Greenfield filter is a 4.6 cm-long cone with six legs that have small curved hooks to facilitate fixation. The spacing between the legs is 2 mm at the apex and 5–6 mm at the base, thus the filter traps most emboli >3 mm diameter. The conical design leads to central filling with thrombus and continued circumferential blood flow causing progressive lysis of the thrombus. This means that up to 80% of the filter can be filled with clot with no increase in distal venous pressure. The filter can be placed surgically or percutaneously. The latter has advantages in terms of patient comfort, procedure time and cost (Hye et al, 1990). Percutaneous insertion requires fluoroscopy and pre-procedure venacavogram. The intravascular sheath is inserted via the right femoral vein, and then the pre-loaded filter with polytetrafluoroethylene (PTFE) guide wire is delivered to the desired level. The carrier is then retracted and the filter springs open. An optional post-procedure venacavogram can be used to verify the position of the device. Follow-up abdominal radiography is used to confirm the position.

Compared with the earlier Mobin-Uddin umbrella, the Greenfield filter had higher patency rates, no proximal migration, minimal distal stasis and was easy to insert (Cimochowski et al, 1980). A rate of recurrent embolism of 4% was reported over a 12-year period in 469 patients (Greenfield and Michna, 1988). Long-term patency rates (not dependent on anticoagulation) are consistently reported at >95% (Cimochowski et al, 1980; Gomez et al, 1983; Greenfield and Proctor, 1995). Similar results have been found when placed supra-renally (needed in cases where the thrombus was at this level, or to avoid contact with the gravid uterus). However, with the 24 Fr stainless steel Greenfield filter there was a 30–40% risk of insertion site venous thrombosis (Kantor et al, 1987). The filter can also be misplaced by premature discharge or inaccurate fluoroscopic control of the carrier.

Titanium Greenfield filter

This development of the Greenfield filter has the same basic shape of the original filter, but is 0.5 cm taller and 8 mm wider at the base. In addition the modified hooks are set at an angle of 80° for stabilization without full penetration of the cava. This modified hook design decreases the rates of filter migration and caval penetration (Greenfield et al, 1989, 1990). Titanium is highly resistant to flexion fatigue and induced corrosion (Greenfield and Savin, 1989), and is just as inert as stainless steel. In addition, the delivery system is different to that of the stainless steel version in that it does not use a guide wire for axial stabilization of the filter during insertion. This can lead to tilting and asymmetry but subsequent alignment of legs has been seen on most follow-up radiographs.

12 Fr Greenfield filter

A 12 Fr stainless steel Greenfield filter was approved by the Food and Drug Administration in 1991 and has been shown to have comparable patency and efficacy to the larger standard 24 Fr Greenfield filter and the titanium Greenfield filter (Cho et al, 1997). The 12 Fr Greenfield filter is made of the same 316 stainless steel as the original Greenfield filter but is taller at 4.9 cm, with a resting basal diameter of 3.2 cm. In addition, two of the hooks are angled distally to facilitate fixation.

Initial trial data showed that in 186 cases 181 (97%) were placed correctly. Four (2%) had not completely opened at insertion (corrected by guide wire manipulation at the time), and one (1%) was misplaced into the lumbar vein. There were nine cases (5%) of leg asymmetry, which was not associated with subsequent recurrent embolism or penetration of the caval wall, and one case (1%) of vena cava perforation. At 30-day follow-up 20 (11%) had filter migration, but it was minimal in most cases (Greenfield et

Table 1. Important caval filters

Filter type	Produced	Description	Efficacy	Complications/notes
Mobin-Uddin umbrella	1969	Silastic membrane connected to six stainless steel spokes	Unknown	Proximal migration, inferior vena cava thrombosis Removed from market 1977
Greenfield stainless steel 24 Fr	1972	Cone with six stainless steel legs in radial formation	Recurrent emboli rate 4%	Insertion site venous thrombosis rate 30–40% Misplacement as a result of premature release or inaccurate fluoroscopic control, but fewer problems with proximal migration and inferior vena cava thrombosis compared with Mobin-Uddin umbrella
Greenfield titanium	1987	Same basic shape as initial Greenfield filter, but taller with a wider base and has modified hooks set at 80°	Recurrent emboli rate <4%	Decreased rates of filter migration and caval penetration compared with original Greenfield filter
Greenfield 12 Fr	1991 (FDA approved)	Same basic shape as initial Greenfield filter, but taller and two hooks are distally angled to facilitate fixation	Recurrent emboli rate 4%	Incorrect placement 3% Filter migration in 11%
Vena Tech	1986	Six angled prongs made of Phynox, each connecting to a stabilizing strut	Occluded filter 8–37% Recurrent pulmonary emboli 2%	Incorrect placement 16% Lower limb oedema commonly reported 29%
Simon Nitinol	1977 (first multicentre trial 1989)	Made of nickel-titanium alloy. Consists of a dome of overlapping loops, above a cone-shaped set of six spokes	Occluded filter 17% Recurrent pulmonary emboli 5%	Lower limb venous stasis 11% Proximal migration 2%
Bird's nest	1984	Four stainless steel wires in a crisscrossing array of non-matching bends	Occluded filter 19% Recurrent emboli 3%	Purported advantages: trap smaller emboli, insert in larger vena cava, no need for intraluminal centring, decreased risk of penetration of caval wall

FDA = Food and Drug Administration

al, 1991). Further follow up at 12 months showed patency of 99% and recurrent pulmonary emboli in 3.7% of the 176 patients still enrolled (Greenfield et al, 1994).

Bird's nest filter

The bird's nest filter was launched by Roehm in 1984 and consists of four stainless steel wires (each 25 cm long and 0.18 mm thick) pre-shaped into a crisscrossing array of non-matching bends (Roehm et al, 1984). This was intended to provide multiple barriers to thromboemboli. The original design was pre-loaded into an 8 Fr PTFE catheter but, again, proximal migration was a problem. It was thus re-designed in 1986 with stiffer 0.46 mm diameter wires to improve fixation (and thus requires a 12 Fr catheter for insertion). The purported advantages include: ability to trap smaller emboli, no need for intra-luminal centring, ability to accommodate large vena cavas up to 40 mm, and the absence of radially-oriented struts, thus decreasing the risk of penetrating the vessel walls.

There are limited long-term follow-up data for the bird's nest filter. The largest study, conducted in 1988, included 481 patients. Of these 440 had a bird's nest filter for 6 months or longer and were followed up by venacavography or ultrasound predominantly. The frequency of recurrent pulmonary thromboembolism was 2.7% and that of inferior vena cava thrombosis was 2.9%. Recurrent pulmonary thromboembolism was confirmed in only two patients, on the basis of pulmonary angiographic findings in one and autopsy findings in the other. Inferior vena cava thrombosis was confirmed using ultrasound in one patient and cavography in six. There were five cases of filter migration which led to the modification of struts. There have been no migrations in the 147 patients treated with the modified-strut bird's nest filter (Roehm et al, 1988).

Simon Nitinol filter

The Simon Nitinol filter was launched in 1977 but preliminary results from a multicentre trial were not available until 1989. The Simon Nitinol filter is made from a nickel-titanium alloy which is pliable when cooled but quickly adopts a rigid shape at body temperature. The filter has a 28 mm dome of eight overlapping loops, with six diverging legs forming a cone below with hooks to engage the caval wall, similar to the Greenfield filter.

In a trial of 103 patients with a Simon Nitinol filter, 44 patients had detailed follow up. Of these, there were seven cases (16%) of caval occlusion, two cases (5%) of recurrent pulmonary embolism, five cases (11%) of lower limb venous stasis and one case (2%) of proximal migration. A further study in 1990 reported similar results (Dorfman, 1990).

Vena Tech filter

The Vena Tech filter was introduced in 1986 and consists of a stamped cone filter of six angled prongs made of Phynox (similar to Elgiloy used in temporary cardiac pacing wires), each connected to a stabilizing strut. This centres and stabilizes it within the inferior vena cava.

The first data for the Vena Tech filter were published in 1988 and involved a sample of 100 patients (Ricco et al, 1988). In this group 98 filters were inserted, of which 82 filters were correctly positioned. Of the 16 that were malpositioned eight had a tilt of 15° or more, five did not open completely, and three had both. These errors were thought to be operator dependent. Regarding outcome, there were two cases (2%) of recurrent pulmonary emboli (of note, both of these cases were in patients where the filter did not open properly). At 1-year follow-up there were four cases (4%) of proximal migration, nine cases (9%) of distal migration, seven cases (8%) of occlusion and 28 cases (29%) of lower limb oedema. More recent trials have showed higher rates of occlusion between 22 and 37% (Millward et al, 1991; Crochet et al, 1993).

Temporary filters

The potential advantages of temporary filters have been of particular interest to orthopaedic surgeons whose patients have a more limited window of risk. However, a number of prohibitive questions remain, including establishing exactly how long the risk period is, and how such filters could be removed without, in the process, dislodging a large embolus and causing a subsequent pulmonary embolism.

Indications for vena caval filter placement

The following are clinical guidelines as to where vena caval filter placement might be appropriate (Rutherford, 2000). Note that efficacy has only been demonstrated in case series rather than larger randomized controlled trials, and in all cases clinical judgment should be used. For a more specific review of the evidence base for specific indications, the British Committee for Standards in Haematology has published specific criteria for filter insertion (Baglin et al, 2006).

The following are clear indications for vena caval filter placement:

1. Documented deep vein thrombosis or pulmonary embolism with a recognized contraindication to anticoagulation
2. Recurrent pulmonary emboli despite adequate anticoagulation.

The following are more controversial relative indications for vena caval filter placement:

1. An ileofemoral thrombosis with a 5 cm or longer free floating tail
2. Septic pulmonary embolism
3. Chronic pulmonary embolism in a patient with cor pulmonale
4. Other high-risk patients (e.g. with occlusion of >50% of the pulmonary vascular bed) who would not tolerate any recurrent thromboembolism
5. Pure prophylaxis in cases of massive trauma
6. Malignancy (Cohen et al, 1991; Rosen et al, 1994; Lossef and Barth, 1995).

Conclusions

Since the Mobin-Uddin umbrella was first launched, a range of filters has been developed. It is important for physicians to be aware of the salient design differences between these filters. Direct comparison of the efficacy and complication rate of different filter types is impossible, as most of the data cited come from retrospective case series, with wide differences in inclusion criteria and follow up. Most filters have similar published patency rates of 3–5%. Variations in complication rates can largely be attributed to differences in follow-up criteria.

While caval filters have an important role to play in preventing venous thromboembolism, the role of optimal medical management and prophylaxis must not be overlooked. The risks of filter insertion and relative cost mean that, for the foreseeable future, caval filters will only be appropriate in a minority of patients with venous thromboembolism. **BJHM**

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Adelson J, Steer ML, Glotzer DJ et al (1980) Thromboembolism after insertion of the Mobin-Uddin caval filter. *Surgery* **87:** 184–9

Amador E, Ting KL, Crane C (1968) Ligation of inferior vena cava for thromboembolism. *JAMA* **206:** 1758–60

Baglin TP, Brush J, Streiff M (British Committee for Standards in Haematology Writing group) (2006) Guidelines on use of vena cava filters. *Br J Haematol* **134**(6): 590—5

Carson JL, Kelley MA, Duff A et al (1992) The clinical course of pulmonary embolism. *N Engl J Med* **326:** 1240–5

Cho KJ, Greenfield LJ, Proctor MC et al (1997) Evaluation of a new percutaneous stainless steel Greenfield filter. *J Vasc Interv Radiol 8*(2): 181–7

Cimochowski GE, Evans RH, Zarins CK, Lu CT, DeMeester TR (1980) Greenfield filter versus Mobin-Uddin umbrella: the continuing quest for the ideal method of vena caval interruption. *J Thorac Cardiovasc Surg* **79:** 358–65

Cohen JR, Tenenbaum N, Citron M (1991) Greenfield filter as primary therapy for deep venous thrombosis and/or pulmonary embolism in patients with cancer. *Surgery* **109**(1): 12–15

Crochet DP, Stora O, Ferry D, Grossetête R, Leurent B, Brunel P, Nguyen JM (1993) Vena Tech-LGM filter: long-term results of a prospective study. *Radiology* **188**(3): 857–60

Dorfman GS (1990) Percutaneous inferior vena caval filters. Radiology **174**(3 Pt 2): 987–92

Gomez GA, Cutler BS, Wheeler HB (1983) Transvenous interruption of the inferior vena cava. *Surgery* **93**(5): 612–19

Greenfield LJ, Michna BA (1988) Twelve-year clinical experience with the Greenfield vena caval filter. *Surgery* **104**(4): 706–12

Greenfield LJ, Proctor MC (1983) Twenty-year clinical experience with the Greenfield filter. *Cardiovasc Surg* **3**(2): 199–205

Greenfield LJ, Savin MA (1989) Comparison of titanium and stainless steel, Greenfield vena caval filters. *Surgery* **106**(5): 820–8

Greenfield LJ, McCurdy JR, Brown PP, Elkins RC (1973) A new intracaval filter permitting continued flow and resolution of emboli. *Surgery* **73:** 599–606

Greenfield LJ, Cho KJ, Pais SO, Van Aman M (1989) Preliminary clinical experience with the titanium Greenfield vena caval filter. *Arch Surg* **124**(6): 657–9

Greenfield LJ, Cho KJ, Tauscher JR (1990) Evolution of hook design for fixation of the titanium Greenfield filter. *J Vasc Surg* **12**(3): 345–53

Greenfield LJ, Cho KJ, Proctor M et al (1991) Results of a multicenter study of the modified hook-titanium Greenfield filter. *J Vasc Surg* **14**(3): 253–7

Greenfield LJ, Proctor MC, Cho KJ et al (1994) Extended evaluation of the titanium Greenfield vena caval filter. *J Vasc Surg* **20**(3): 458–64; discussion 464–5 (Erratum in: *J Vasc Surg* **21**(1 1995): 162)

Homans J (1934) Thrombosis of deep veins of lower leg, causing pulmonary embolism. *N Engl J Med* **211:** 993–7

Hye RJ, Mitchell AT, Dory CE, Freischlag JA, Roberts AC (1990) Analysis of the transition to percutaneous placement of Greenfield filters. *Arch Surg* **125**(12): 1550–3

Kantor A, Glanz S, Gordon DH, Sclafani SJ (1987) Percutaneous insertion of the Kimray-Greenfield filter: incidence of femoral vein thrombosis. *AJR Am J Roentgenol* **149**(5): 1065–6

Kearon C (2001) Epidemiology of venous thromboembolism. *Semin Vasc Med* **1**(1): 7–26

Lossef SV, Barth KH (1995) Outcome of patients with advanced neoplastic disease receiving vena caval filters. *J Vasc Interv Radiol* **6**(2): 273–7

Mansour M, Chang AE, Sindelar WF (1985) Interruption of the inferior vena cava for the prevention of recurrent pulmonary embolism. *Am Surg* **51:** 375–80

Miller TD, Staats BA (1988) Impaired exercise tolerance after inferior vena caval interruption. *Chest* **93:** 776–80

Millward SF, Marsh JI, Peterson RA et al (1991) LGM (Vena Tech) vena cava filter: clinical experience in 64 patients. *J Vasc Interv Radiol* **2**(4): 429–33

Mobin-Uddin K, McLean R, Bolooki H, Jude RJ (1969) Caval interruption for prevention of pulmonary embolism. Long-term results of a new method. *Arch Surg* **99:** 711–15

Moretz WH, Rhode CM, Shepherd MH (1959) Prevntion of pulmonary emboli by partial occlusion of the inferior vena cava. *Am Surg* **25:** 617–26

Nasbeth DC, Morgan JM (1965) Reassessment of the role of inferior vena cava ligation in thromboembolism. *N Engl J Med* **273:** 1250–3

Ochsner A, DeBakey M (1943) Intravenous clotting and its sequelae. *Surgery* **14:** 679

O'Neil EE (1945) Ligation of the Inferior vena cava in the prevention and treatment of pulmonary embolism. *N Engl J Med* **252:** 641–6

Ricco JB, Crochet D, Sebilotte P et al (1988) Percutaneous transvenous caval interruption with the "LGM" filter: early results of a multicenter trial. *Ann Vasc Surg* **2**(3): 242–7

Roehm JO Jr, Gianturco C, Barth MH, Wright KC (1984) Percutaneous transcatheter filter for the inferior vena cava. A new device for treatment of patients with pulmonary embolism. *Radiology* **150**(1): 255–7

Roehm JO Jr, Johnsrude IS, Barth MH, Gianturco C (1988) The bird's nest inferior vena cava filter: progress report. *Radiology* **168**(3): 745–9

Rosen MP, Porter DH, Kim D (1994) Reassessment of vena caval filter use in patients with cancer. *J Vasc Interv Radiol* **5**(3): 501–6

Rutherford RB (2000) Caval interruption procedures. In: Rutherford RB, ed. *Vascular Surgery.* 5th edn. WB Saunders, Philadelphia, PA: 1968–78

Silverstein MD, Heit JA, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ 3rd (1998) Trends in the incidence of deep vein thrombosis and pulmonary embolism: a 25-year population-based study. *Arch Intern Med* **158:** 585–93

Trousseau A (1868) Phlegmatia alba dolens. In: *Clinique Médicale de l'HôtelDieu de Paris*. 3rd edn. Baillère, Paris: 652–95

KEY POINTS

- Caval interruption is the treatment of choice for the prevention of recurrent pulmonary embolism in patients with recognized contraindication to anticoagulation.
- The role of optimal medical management and prophylaxis must not be overlooked in patients with caval interruption.
- Long-term complications occur in a minority of patients and include recurrent pulmonary embolus, caval occlusion and caval filter migration.
- Overall, the benefits of preventing pulmonary embolism far exceed the risks related to filter placement in properly selected patients.