Prophylactic and Therapeutic Inferior Vena Cava Filters to Prevent Pulmonary Emboli in Trauma Patients

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Hypothesis: Insertion of inferior vena cava filters (IVCFs) can prophylactically reduce pulmonary embolism (PE) in trauma patients.

Design: Retrospective review.

Setting: Urban, level I trauma center.

Patients: Two hundred blunt trauma patients undergoing IVCF placement.

Interventions: In 122 patients who had already been diagnosed as having deep vein thrombosis (DVT) (112 patients) and/or PE (22 patients), the insertion of the IVCF was considered “therapeutic.” In 78 patients who had no evidence of DVT or PE but who were considered to be at high risk for a PE, the IVCF was considered “prophylactic.”

Main Outcome Measures: Incidence of PE and related mortality and morbidity in therapeutic vs prophylactic IVCFs.

Results: The number of prophylactic IVCFs inserted increased significantly from only 4% (3/68 cases) from 1991 through 1996, up to 57% (75/132 cases) from 1997 to June 2001. Although the mean±SD age (51±20 years vs 41±15 years; \(P<.001\)) was higher in the therapeutic group, there was no difference in the mean±SD Injury Severity Scores (20±12 vs 21±11). Therapeutic filters were placed much later after injury (mean±SD time, 11±7 vs 3±2 days; \(P<.001\)). The mortality rate was 11% (13/122 patients) in patients having a therapeutic IVCF, as compared with only 3% (2/78 patients) in those placed prophylactically (\(P=.07\)). None of the patients who had placement of a prophylactic IVCF developed subsequent PE. The incidence of PE decreased in all blunt trauma patients from 0.29% before 1997 to 0.15% after January 1, 1997, when 57% of the IVCF inserted were prophylactic (\(P=.06\)).

Conclusions: Prophylactic IVCFs should be inserted within 48 hours of injury in specific trauma patients at high risk for PE and with contraindications to anticoagulation.

Arch Surg. 2002;137:521-527

INFEROIR VENA cava filters (IVCFs) are being used with increasing frequency in trauma patients because of the heightened risk of deep vein thrombosis (DVT) and threat of subsequent pulmonary embolism (PE). The incidence of DVT in trauma patients may be as high as 20% to 58%, and the true incidence of PE is unknown.1,2 Unfortunately, some investigators have found that routine thromboembolism prophylaxis with sequential compression devices (SCDs), and low-dose heparin sodium is relatively ineffective in high-risk trauma patients.3,4 Additionally, many patients are not candidates for anticoagulation because of their associated traumatic injuries, and SCDs may be difficult to place on patients with major long-bone fractures.

Clinical signs of DVT are generally absent, and fatal PE frequently occurs without prior warning, with only a third of fatal PE cases diagnosed before death.3,5 Thus, insertion of IVCFs in high-risk trauma patients prior to DVT and/or PE should be able to reduce the incidence of lethal PE. The development of safe and effective, percutaneously placed IVCFs has stimulated an increase in the use of prophylactic IVCFs in high-risk trauma patients in an effort to reduce the incidence of PE.6,7 Some institutions have noted a decreased incidence of PE in trauma patients with prophylactic IVCFs.8-13 Others, however, have demonstrated conflicting results, noting no difference or an actual increase in the incidence of PE with prophylactic IVCFs.14,15 The purpose of this study was to review our results with the use of both prophylactic and therapeutic IVCFs performed at a level I trauma center throughout a 10½-year period.

RESULTS

There was a total of 200 patients with an average age of 47±19 years, and two thirds (66.5%) were male. The average ISS
PATIENTS AND METHODS

This is a retrospective review of the records of 200 patients who were admitted to Detroit Receiving Hospital (Detroit, Mich.) between January 1, 1991, and June 10, 2001, with blunt traumatic injuries and who received IVCFs. The data were derived from medical records and from trauma mortality and morbidity meetings conducted once each month with a representative of the medical examiner’s office, who performed autopsies on all trauma deaths. Data collected included demographics, injuries, Injury Severity Score (ISS), reason for IVCF placement, site of IVCF insertion, DVT, PE, anticoagulation complications, length of stay, and mortality rate (MR).

In 122 patients, the insertion of the IVCF was considered “therapeutic” because these patients had contraindications to anticoagulation and required treatment for DVT in 100 patients, PE in 10, and both DVT and PE in 12. Contraindications to anticoagulation included traumatic brain injury (40%), major pelvic and/or acetabular fractures (24%), spinal cord injury (13%), spleen or liver injury (7%), gastrointestinal bleeding (6%), hematuria (6%), stroke (3%), and traumatic aortic rupture (1%).

In 1997, we adopted a policy, in coordination with the orthopedic surgeons, to place prophylactic IVCFs in high-risk trauma patients with contraindications to anticoagulation and barriers to the use of meaningful SCDs. This included patients with either major pelvic and/or acetabular fractures in association with lower extremity long-bone fractures, or in patients with bilateral lower extremity long-bone fractures. This policy was almost uniformly accepted; thus, virtually all patients meeting these criteria had prophylactic IVCFs inserted. As a consequence, the use of prophylactic IVCFs increased, and by July 2001, 78 patients who had no evidence of DVT or PE, but who were considered to be at high risk for a PE by the attending trauma surgeon, had a prophylactic IVCF.

The project and data processing were approved by the Wayne State University Human Investigation Committee (Detroit). Univariate χ² analysis was performed with Sigma Stat version 1.0 (SPSS Inc, Chicago, Ill), and analysis of variance was performed using JMP version 3.2 statistical software (SAS Institute Inc, Cary, NC). Data are expressed as means ± SDs. Statistical significance was assumed at P < .05.

was 20±11. The injuries in the 78 patients with a prophylactic IVCF included spine injuries (19 patients), head injuries (18 patients), and the following 161 fractures: pelvis (38 patients), acetabulum (38 patients), tibia-fibula (29 patients), foot and/or ankle (21 patients), femur shaft (20 patients), knee (9 patients), and hip (6 patients). Most of the IVCFs were percutaneously placed via the internal jugular vein (72%), with the remainder placed using a femoral vein approach. The great majority (94%) of the IVCFs were inserted by trauma surgeons, while the others were placed by interventional radiologists, usually in conjunction with a pulmonary arteriogram.

Four patients with therapeutic IVCFs had significant complications associated with anticoagulation prior to insertion of the IVCF. These complications included 2 gastrointestinal hemorrhages, 1 episode of hematuria, and 1 episode of heparin-induced thrombocytopenia. Three of these complications were due to systemic heparinization—2 for treatment of patients with PE, and the other for treatment of a proximal lower extremity DVT. There were no anticoagulation complications in the patients having prophylactic IVCF. In patients with prophylactic IVCF, the use of SCDs was routine when possible, and there was variable use of subcutaneous low-dose heparin.

THERAPEUTIC VS PROPHYLACTIC

Of the 200 patients with IVCF, 122 (61%) were placed therapeutically. Of the 100 patients who had only a DVT, 6 (6%) died, and of the 22 having a PE (with or without a DVT), 7 (32%) died, for an overall MR of 11% (13/122).

Of the 78 patients having a prophylactic IVCF, 2 (4%) died—both of sepsis with multiple organ failure. Five patients (6%) developed a DVT after the IVCF placement, and none developed a PE. There was a trend toward a decreased mortality rate in patients undergoing prophylactic IVCF (4%), compared with those filters placed therapeutically (11%) (χ²=3.4; P = .07).

The venous access site used for percutaneous placement of IVCF was either the internal jugular or the femoral vein. Of the 72% of patients who had jugular venous access for IVCF, only 5 had a subsequent or recurrent DVT, while none were identified with the femoral approach. When comparing the neck vs the groin approach for inserting the IVCF, there were no significant differences in any of the parameters examined, including age, length of stay, ISS, and mortality or morbidity.

The average age of patients with therapeutic IVCF was 51±20 years, which was significantly higher than that of 41±15 years in those patients with prophylactic IVCF (P < .001). However, there was no significant difference in the ISS of those receiving IVCFs for therapeutic (20±12) compared with prophylactic (21±11) indications. The length of stay was also not significantly different in these 2 groups, with patients staying 29±21 days in the therapeutic group vs 25±19 days in the prophylactic group.

A significantly longer time until IVCF insertion was noted in the patients having therapeutic IVCF (11±7 days) compared with those having prophylactic IVCF (3±2 days) (P < .001). This difference in hospital day of filter placement is important since 50% (11/22) of our patients sustained PE within the first week of injury. On average, the PE was diagnosed 4±2 days from admission. Furthermore, there was a significant reduction in the rate of PE’s because none of the patients with a prophylactic IVCF had a PE, compared with 22 patients (18%) in the therapeutic group (χ²=14; P < .001). Of the 22 patients with a PE, the MR was 32% (7/22 patients), while of the 178 patients without a PE, the MR was only 4.5% (8/178 patients) (P < .001) (Table 1). Of the patients dying without a PE, 6 died of sepsis with multiple organ failure, and 2 of traumatic brain injury.
TRENDS BY YEAR

From 1991 through 1996, only 3 prophylactic IVCFs were inserted, the percentage increased progressively from 44% (7/16 patients) in 1997 to 63% (15/24 patients) in the first half of 2001 (Table 2). This correlated with a statistically significant increase in the use of prophylactic IVCFs (4% [3/68 patients]) from 1991 through 1996, compared with 57% (75/132 patients) thereafter ($X^2 = 49.6; P < .001$). Furthermore, there was an increase in the total use of IVCFs for blunt trauma patients, with an average rate of 11 IVCFs per year in the earlier period vs 29 per year after 1996.

The MR in patients receiving IVCFs from 1991 through 1996 was 13% (9/68 patients), while a downward trend was demonstrated after 1996, with an MR of only 5% (6/132 patients; $P = .05$); however, of the 15 total deaths, only 3 (20%) were primarily due to PE, with deaths occurring on days 15, 21, and 21, respectively, of their hospitalizations. One of these 3 patients died of a massive saddle pulmonary embolus 14 days after placement of the IVCF, and clot was found in the IVCF at autopsy. The other 2 patients were relatively unstable due to PE, and 1 patient died intraoperatively soon after IVCF insertion, while the other patient died within 24 hours postoperatively. Four other patients also had pulmonary emboli, but they died primarily of sepsis and traumatic brain injuries at 6, 8, 22, and 108 days. Indeed, of the 15 deaths in patients with a pulmonary embolus, 11 (73%) died primarily of sepsis with multiple organ failure. Of the 5 patients with severe head injuries who died, 4 also had severe sepsis. The average ISS of the patients who died was $33 \pm 15$, which was significantly higher than the ISS of $19 \pm 10$ in those who lived ($P < .001$).

When we reviewed the incidence of PE diagnosed in all blunt trauma patients admitted to our institution, we noted a decreasing incidence of PE with greater use of prophylactic IVCFs. Specifically, from 1991 through 1996, the PE rate was 0.29% (32/11050), and this dropped by nearly half (to 0.15%) for the period after 1996 (12/8226; $P = .05$), during which time the rate of prophylactic IVCF insertion increased significantly (Table 3).

The increased risk of DVT and PE in trauma patients, along with the relative ineffectiveness of standard prophylaxis, has lead to the increased use of prophylactic IVCFs. This has been demonstrated in our study by the increase in incidence of prophylactic IVCFs in blunt trauma patients from only 4% in the 1991-1996 period, to 57% after 1996. Similarly, in studies by Greenfield and Proctor,6,15 the incidence of usage of prophylactic IVCFs went from 13% in the period between 1972 and 1992, to 46% since 1995. Because of the increased risk of PE, in 1997 we began to insert prophylactic IVCFs in patients at high risk for thromboembolic complications and obvious contraindications to anticoagulation; specifically, those patients with major pelvic and/or acetabular fractures associated with lower extremity long-bone fractures and those with bilateral lower extremity long-bone fractures.

The risk factors for thromboembolism in trauma patients has been reviewed by several authors. Rogers et al17 identified 3 high-risk groups with a relative risk of PE that was 21 to 54 times that of the general trauma patients, including patients with severe head injury and coma, spinal cord injury with neurologic deficit, and combined pelvic and long-bone fractures. Using serial impedance plethysmography and contrast venography in trauma patients, a multivariate analysis by Geerts et al12 identified 5 independent risk factors for DVT. These included older age, blood transfusion, surgery, femur or

### Table 1. Comparison of Therapeutic and Prophylactic IVCFs*

<table>
<thead>
<tr>
<th></th>
<th>Therapeutic (n = 122)</th>
<th>Prophylactic (n = 78)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD age, y</td>
<td>51 ± 20</td>
<td>41 ± 15</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Mean ± SD ISS</td>
<td>20 ± 12</td>
<td>21 ± 11</td>
<td>.51</td>
</tr>
<tr>
<td>Mean ± SD LOS</td>
<td>29 ± 21</td>
<td>25 ± 19</td>
<td>.22</td>
</tr>
<tr>
<td>Mean ± SD HDFP</td>
<td>11 ± 7</td>
<td>3 ± 2</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Mean PE, % (No.)</td>
<td>18 (22)</td>
<td>0 (0)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Mean MR, % (No.)</td>
<td>11 (13)</td>
<td>3 (2)</td>
<td>.07</td>
</tr>
</tbody>
</table>

*IVCFs indicates inferior vena cava filters; ISS, Injury Severity Score; LOS, length of stay; HDFP, hospital day of filter placement; PE, pulmonary embolism; and MR, mortality rate.

### Table 2. Therapeutic and Prophylactic IVCFs: 1991-1996 and 1997 to June 2001*

<table>
<thead>
<tr>
<th>Year</th>
<th>Therapeutic, No. (%)</th>
<th>Prophylactic, No. (%)</th>
<th>All No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-1996</td>
<td>11 (100)</td>
<td>0 (0)</td>
<td>7</td>
</tr>
<tr>
<td>1992</td>
<td>7 (88)</td>
<td>1 (12)</td>
<td>8</td>
</tr>
<tr>
<td>1993</td>
<td>15 (94)</td>
<td>1 (6)</td>
<td>16</td>
</tr>
<tr>
<td>1994</td>
<td>14 (83)</td>
<td>1 (7)</td>
<td>15</td>
</tr>
<tr>
<td>1995</td>
<td>14 (100)</td>
<td>0 (0)</td>
<td>14</td>
</tr>
<tr>
<td>1996</td>
<td>8 (100)</td>
<td>0 (0)</td>
<td>8</td>
</tr>
<tr>
<td>Total 1991-1996</td>
<td>65 (96)</td>
<td>3 (4)†</td>
<td>68</td>
</tr>
<tr>
<td>1997-June 2001</td>
<td>9 (56)</td>
<td>7 (44)†</td>
<td>16</td>
</tr>
<tr>
<td>1998</td>
<td>8 (44)</td>
<td>10 (56)</td>
<td>18</td>
</tr>
<tr>
<td>1999</td>
<td>14 (39)</td>
<td>22 (61)</td>
<td>36</td>
</tr>
<tr>
<td>2000</td>
<td>17 (45)</td>
<td>21 (55)</td>
<td>38</td>
</tr>
<tr>
<td>2001</td>
<td>9 (37)</td>
<td>15 (63)</td>
<td>24</td>
</tr>
<tr>
<td>Total 1997-June 2001</td>
<td>57 (43)</td>
<td>75 (57)†</td>
<td>132</td>
</tr>
</tbody>
</table>

*IVCFs indicates inferior vena cava filters. †P < .001.

### Table 3. Pulmonary Embolism Rates 1991-1996 vs 1997 to June 2001 in All Blunt Trauma Patients*

<table>
<thead>
<tr>
<th>Year</th>
<th>Total No. of Blunt Trauma Admissions</th>
<th>PE With All Blunt Trauma Admissions, % (No.)</th>
<th>MR in Blunt Trauma Admissions With PE, % (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-1996</td>
<td>11050</td>
<td>0.29 (32)</td>
<td>34 (11)</td>
</tr>
<tr>
<td>1997 to June 2001</td>
<td>8226</td>
<td>0.15 (12)†</td>
<td>25 (3)</td>
</tr>
</tbody>
</table>

*PE indicates pulmonary embolism; MR, mortality rate. †P = .05.
tibia fracture, and spinal cord injury. Patients with femur or tibia fractures were almost 5 times as likely to develop a DVT, while patients with spinal cord injuries were more than 8 times as likely to develop a DVT. A study by Winchell et al demonstrated 4 groups of patients at high risk for PE, with a relative risk approximately 10 times greater than that of the control group. These included patients with combined head and spinal cord injury, head and long-bone fracture, severe pelvis and long-bone fracture, and multiple long-bone fractures. Fifty-one (65%) of our patients having prophylactic IVCFs had injuries corresponding to 1 of Winchell's 4 high-risk groups. Of the remaining 27 patients not meeting strict Winchell criteria, 15 had complex pelvic fractures, 6 had combined complex pelvic and spine injuries. Of the remaining 6 patients, 5 had traumatic brain or spine injuries and 1 had an isolated femur fracture with heparin-induced thrombocytopenia.

None of our patients in the prophylactic group developed a PE, and none of the patients in the therapeutic group who had IVCF placement for only DVT developed a PE. Thus, all 178 blunt trauma patients from 1991 to June 2001 who had an IVCF and who were without an antecedent PE were protected from a subsequent PE. We identified all clinically relevant pulmonary emboli by any significant hemodynamic or pulmonary compromise. Subsequent diagnosis was determined by ventilation perfusion scanning and pulmonary angiography as indicated. Even though some small pulmonary emboli might have escaped the IVCFs, there were none of any clinical significance. Although our follow-up relies on hospital data, including an average of 5 weeks post-IVCF insertion (3 weeks inpatient followed by 2 weeks at our rehabilitation facility), the most dangerous time for PE is thought to be early after injury. In this study, 50% (11/22 patients) of PE cases occurred within the first week of injury, occurring at a mean ± SD of 4 ± 2 days after injury; and more than a third (8/22 patients) occurred in the first 72 hours. Of 63 trauma patients with PE, Owings et al reported that 60% occurred within the first week of injury, and 4 patients had a PE documented on day 1 following injury. Thus, early placement of prophylactic IVCFs (within 48 hours) would be required to protect many patients from PE.

In a 5-year follow-up of trauma patients receiving prophylactic IVCFs, the rate of new PE was only 2.3% and was identified only in patients with strut malposition or filter tilt of 14° or more. Only 1 of our patients in the therapeutic group developed a recurrent, massive, fatal PE 2 weeks after IVCF insertion, with clot demonstrated in the IVCF at autopsy. Furthermore, a long-term outcome study across more than 20 years of all hospitalized patients with proximal DVTs who were without anticoagulation alone, Decousus et al demonstrated a reduction in the rates of early PE; however, there was no difference in the rate of PE after cessation of anticoagulation, and there was no difference in the MR at 2 years' follow-up. Additionally, patients with IVCFs demonstrated a significantly higher rate of DVT recurrence than those treated with anticoagulation alone. McMurtry et al retrospectively reviewed 248 trauma patients throughout different time periods of low and high prophylactic IVCF use. The overall incidence of PE during years of high prophylactic IVCF use was actually significantly higher, 0.48%, compared with 0.31% during years of low prophylactic IVCF use (P < 0.05).

In reviewing the incidence of PE and MR in all our blunt trauma patients, we identified a 0.29% (32/11,050) incidence of PE during the early period of low prophylactic IVCF use. After January 1, 1997, in the period of high prophylactic IVCF use (17 IVCFs per year), the incidence of PE decreased to 0.15% (12/8226). Thus, if we extrapolate the data and prophylactic IVCFs had been placed at the higher rate during the earlier period, the number of patients with PE during this time might have been reduced to 17, with only 6 deaths. In effect, we would have prevented 15 cases of PE and 5 deaths. Thus, for every 20 prophylactic IVCFs inserted in our high-risk trauma patients, 3 PE cases and 1 death are prevented.

In conclusion, the use of prophylactic IVCFs should be considered in trauma patients at high risk for PE and obvious contraindications to anticoagulation and barriers to meaningful use of SCDs. In particular, patients with major pelvic fractures in combination with lower extremity long-bone fractures, or patients with bilateral lower extremity long-bone fractures, should have pro-
phylactic IVCFs inserted early after injury (within 48 hours) to be most effective in preventing PE.

This study was presented at the 109th Scientific Session of the Western Surgical Association, San Antonio, Tex, November 13, 2001.

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REFERENCES


DISCUSSION

George C. Velmahos, MD, Los Angeles, Calif. The existing literature on the prevention of venous thromboembolism is confusing. Some authors support the need for aggressive thromboprophylaxis while others argue against it. When the selected method of thromboprophylaxis is inferior vena caval filters, then things become even more confusing. A recent evidence-based report emphasized the absence of level 1 evidence on the role of inferior vena caval filters. Our scientific opinions about inferior vena cava filters are based on studies that have methodological limitations due to retrospective design or comparison with historical controls.

With that in mind, I would like to congratulate Drs Tyburski, Wilson, and their continuously productive group from the Detroit Receiving Hospital for a very interesting study. After analyzing 200 patients with therapeutic or prophylactic vena cava filter placement over 10 years, the authors encourage us to use vena caval filters prophylactically in selected trauma patients.

Although I intuitively agree with the authors’ conclusion, I would like to offer 4 questions on issues that require further clarification and, for the sake of discussion, I will argue on each of these questions that prophylactic vena caval filter placement is not necessary.

1. I followed your math, but I am not sure, Dr Tyburski, that I fully understood it. But the essence is that you had 3 patients die from pulmonary embolus. Two were before filter placement and 1 after filter placement. Obviously filter placement did not reduce PE-related mortality, exactly the outcome that we would like to see. Further, inferior vena cava filter placement causes complications. A New England Journal of Medicine prospective randomized trial suggested that vena caval filter placement increases the incidence of DVT. About one third of patients with DVT will suffer significant long-term morbidity from possible postphlebitic syndrome. If the rate of PE-related deaths is so low as you suggested, approximately 1 death every 3 years in your study, but the morbidity of placing devices to prevent PE-related death is so significant, should we be placing vena caval filters prophylactically?

2. Although prophylactic vena caval filter placement did not reduce PE-related mortality, you showed that it was associated—not caused by, but associated with—less overall mortality. To me, this means that your prophylactic and therapeutic groups were simply not the same. Ensuring similarity of the 2 groups only on the basis of injury severity score is flawed. If the 2 groups are not similar and the difference in overall mortality rates is due to inherent differences and not the inferior vena caval filter used, then what is the proof that it is of any benefit? In short, could you convince us that these 2 groups are comparable?

3. This is a methodological question that leads to outcomes. How did you diagnose PE? Did you use different methods of diagnosis over these 10 years? We have shown that the increasingly used CT [computed tomography] angiogram is not as sensitive as the time-honored pulmonary angiogram in diagnosing PE after trauma, particularly peripheral PE. You may have been missing PE’s lately if you attempt to use mostly CT angiograms, and that, rather than the use of prophylactic vena caval filters, could account for the decreased incidence of PE in the later period of your study compared to the earlier period.

4. Which do you think is the origin of pulmonary embolus? We have not found a strong correlation between clots in the lungs and clots in the lower extremities, and neither did you. If the origin is not in the lower extremities, then what is really the role of inferior vena caval filters?

By these questions I would not wish to be perceived as an opponent to inferior vena cava filter placement. There is certainly a role for these potentially life-saving devices. However, this role remains unclear. Because the coagulation disorders after trauma are not thoroughly studied, the methods of diagnosis, prevention, and treatment are still inadequate. There is a huge need and opportunity for additional research. I would like to thank the authors for adding to our knowledge by their study.

M. Ashraf Mansour, MD, Maywood, Ill. Can you tell us what types of filters you placed: Greenfield filters or other types? Do you place them in the operating room, interventional suite,
or do you do any at the bedside, as some groups have suggested that they can be placed at the bedside in critically ill patients? Do you have any experience with the temporary filters, the TRAP-EASE that has been recently introduced? Finally, what is your timing? If a patient is going to the operating room for an orthopedic procedure, do you insert the filter before or after the procedure or do you do it independently?

Christine S. Cocanour, MD, Houston, Tex: Do you still use low-molecular-weight heparin on your patients who don't have a contraindication to heparinization to prevent DVT and its complications? Is there a role for temporary filters in trauma patients?

Gregory J. Jurkovich, MD, Seattle, Wash: Dr Tyburski and Dr Wilson, I want to congratulate you on, first of all, developing a protocol for managing venothromboembolism prophylaxis in trauma patients, instituting it in your institution, and carrying through on that policy. That often can be difficult. You have accomplished that first task and now have a nice patient population pool from which to draw some conclusions. I must say, however, that I find the conclusions to be questionable, and I cannot support them for a variety of reasons. But perhaps most pressing to me is the reason raised by Dr Velmahos in what I thought was an excellent discussion, and that is that the comparisons you made were based on your understanding of the incidence of pulmonary embolism before and the incidence of pulmonary embolism after changing the policy regarding IVC filters. There is a number of things that can change the incidence of a disease that really haven't been addressed in this discussion, and I will raise 4 of them, and there probably are others. But the 4 that come to my mind are:

1. The type of patient, age, gender, ethnicity or race, the characteristics of the patient themselves. Were they different before and after this policy was introduced?

2. The type of injury, both injury mechanism as well as injury severity, and not simply injury severity score, but exactly the type of injuries that occur before vs after this policy.

3. The role of screening, again raised by George, whether it was prepolicy pulmonary angiogram vs postpolicy CT angiogram, could have a significant impact.

4. And then, finally, there are coding reasons. How many of these are simply coded by registers or hospital discharge summaries? There may have been a difference in the coding policy within the hospital for financial or other reasons. I simply rise to say that if the premise of this is based on the incidence of pulmonary embolism, there are many things that can affect incidence, and those should at least be examined in the report.

Scott Norwood, MD, Tyler, Tex: There is conflicting information in the literature concerning long-term follow-up of patients who have inferior vena caval filters placed prophylactically. One study from the Allentown Trauma Group in 1997 showed that there was about a 44% incidence of DVT following placement of prophylactic vena caval filters and a 10% rate of persistent lower extremity edema at 29 months' follow-up. Greenfield and Proctor at the University of Michigan also reported a 1.3% incidence of pulmonary embolus following prophylactic filter placement and an 11% incidence of DVT.

My question is, do you have any long-term follow-up on your patients, and, if you do, based on your follow-up, what is your opinion concerning the filter as a potential risk factor for future episodes of venous thromboembolism in patients who have had filters placed solely for prophylaxis?

John A. Weigelt, MD, Milwaukee, Wis: Very nice presentation, Jim, but I have a few questions and a comment. The first is the diagnostic method of PE, which is very important. I disagree with George, as helical CT is going to be the standard that we will use. It is extremely sensitive, and if the same diagnostic technique was not used in the 2 groups, the comparison must be considered suspect. The second question is whether your outcomes assessment is valid. You told us the positive aspects of the filter. What were the negative aspects? Was there any morbidity from filter placement?

Finally, your range of PEs, 0.1 to 0.3, is consistent with every report that is in the literature already and, as you pointed out, there is no statistical difference between those 2 numbers.

David S. Robinson, MD, Kansas City, Mo: I want to congratulate the authors on a fine paper. I have 3 questions. First, when a pulmonary embolism occurs after a vena cava filter has been placed, it appears that the filter has failed because an embolism has passed through it, but I wonder how many of these patients also had subclavian and upper extremity trauma. Second, in extension of a question asked earlier, in long-term follow-up, how many of these people developed significant problems of lower extremity edema or other complications? I realize this assessment is difficult to separate from the consequence of the pelvic fracture itself. Finally, how many patients, once they were stabilized, were placed on long-term anticoagulation, and, if they were, how long did you continue coumadin anticoagulation?

J. David Richardson, MD, Louisville, Ky: Jim, if I could just make a comment—and I won't ask a question (I know you have plenty of questions)—but for those of you who don't follow this literature, it is a very important topic. The hard issue is "prophylaxis" rather than the therapeutic filters. One talks about very high-risk lesions that would probably include pelvic fractures, spinal cord injury, and head injuries. The tendency often is to include a lot of other lesions as high risk.

These often include multiple lower extremity fractures. So the bar gets lowered for the placement of a filter. Often the phrase "standard of care" has crept into the literature and implies that any patient at "high risk" has a prophylactic filter placed. These are major cost issues and major medicolegal concerns.

Dr Tyburski: I want to thank all of the discussants, particularly Dr Velmahos, who was kind enough to share his thoughts with me ahead of time. I will try to answer these as best I can. Dr Velmahos, we didn't have any PEs in the true prophylactic group. All 22 PEs were in the therapeutic group. The lower mortalities using the math I used, I assumed that our death rate in patients who had pulmonary embolism in the blunt trauma would be 25%, which is what we encountered in the trauma population, and even though only 3 of the deaths could be directly attributed to the PE, on review, we thought that the PE's probably contributed to the death rate of the patients who didn't die primarily due to the PEs. These people were in the ICU (intensive care unit) and I think the PE contributed to their demise.

The diagnosis of PE is a tough one. I think we were fortunate, in a left-handed way, that our radiologists aren't big on the spiral CT scan yet, so most of the PEs were diagnosed first by clinical suspicion and then by VQ [ventilation-perfusion] scan, and several of them were diagnosed with pulmonary angiogram. That gets into the point of where the filters were placed. Ninety-four percent of the filters were placed by surgeons in the operating room; the other 6% were people getting diagnostic pulmonary angiograms; the interventional radiologist went ahead and placed the filters. We did try to use all our clinical data, and all trauma deaths were reviewed along with the medical examiner, so those were all autopsy-proven pulmonary emboluses—the 22 in this series.

The source of the PE? That's a good question. The one patient who did have a therapeutic vena caval filter placed died of a massive saddle embolus with the vena caval filter in place in good position on autopsy with a large amount of clot around it and a large saddle embolus in the pulmonary arteries. Did that come from the filter? I can't tell you. Obviously without DVT's also they can come from the pelvic veins. A lot of these patients did have subclavian catheters and supraclavarian and upper-extremity fractures. Certainly that could be a source.
Ash, thanks for your comments. As I said, 94% of them were placed in the OR [operating room] by the trauma surgeons. The timing on these: we tried to do it as soon as we can, so if a patient is going to the operating room for an orthopedic procedure, we generally do the filter before the orthopedic guys manipulate the bones around too much. All the devices were Greenfield filters.

Dr Cocamour, yes, we do try to use low-molecular-weight heparin. I have to congratulate Dr Scott Norwood. I think the only thing the orthopedic surgeons and the neurosurgeons look at in trauma patients is if they are on any anticoagulation. They don’t care about the vents, they don’t care if they get any nutrition, but they do care if they are getting low-molecular-weight heparin. We have had several discussions, and they are very reticent and will write in the chart that these patients are completely contraindicated to any low-molecular-weight heparin that puts the primary team in a fairly unsteady footing. This speaks to the issues that Dr Richardson brought up about medicolegal concerns.

Dr Jurkovich, on the incidence of pulmonary embolism, I can only tell you that the patients haven’t changed that much, except we do have a few more blunt trauma patients as we have become a referral base now for bad pelvic injuries and acetabular fractures. All of these injuries were blunt. There were no penetrating injuries. Again, we don’t use CT angiograms much yet, though that is increasing.

The database that we got this from was not just the coding; this was done from an extensive review of the medical records, and part of that was from one of the senior authors, several thousand 3 x 5 cards on which he records every trauma patient that goes into Detroit Receiving Hospital, including every mortality that has been in the hospital since 1980.

Dr Norwood, we do use the filters for the patients at risk for thromboembolism. We did not have long-term follow-up on a lot of them, but we did have follow-up all through the hospital and all through the rehab period.

Dr Weigelt, you brought up the assessment of complications. There were no deaths that we could attribute to the filters. I did mention the incidence of the recurrent, new, or subsequent deep venous thrombosis that occurred on the patients that did have the filters placed. They were, interestingly, all through the jugular approach. We did have some placement complications that I know of. There was 1 patient that required a transfusion after a filter was placed for retroperitoneal hematoma. There were 2 patients who had pericardial effusions, 1 requiring a thoracotomy, probably from a guidewire puncture of the right ventricle. That patient survived and actually did well, but certainly that would be listed as a major morbidity from this procedure.

We do try to anticoagulate these patients as quick as we can. Finally, the use of a temporary filter; I think that would be an excellent idea because we do put these in for a long period. I don’t know the long-term thrombosis rate of the vena cava or the iliacs in these patients.

I want to thank the society and the discussants for the ability to present these data.

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**Surgical Anatomy**

The deep posterior compartment contains the posterior tibialis, flexor hallucis longus, and flexor digitorum longus muscles; the tibial nerve; and the posterior tibial and peroneal arteries.