While caring for a professional American football team, the senior author (R.F.W.) has had experience with a number of players with kidney disorders. In 1 case, the player suffered a significant kidney laceration and was unable to play for several months (Figure 1). In another case, a player was found to have a congenital hydronephrosis, markedly limiting the function of 1 kidney (Figure 2). In this case, given the concern over playing with only 1 functional kidney, it would have been helpful to have an idea of how often players suffer traumatic kidney injury and the typical sequelae of such an injury.
Contact sports such as American football are associated with a number of abdominal injuries, including renal trauma. Most of the data in the literature comes from the pediatric population, in which 16% to 30% of renal trauma has been shown to be sports related. In one study reviewing the National Pediatric Trauma Registry recording data from 50 United States pediatric trauma centers for 1990 to 1999, 42 sports-related traumatic kidney injuries were reported; 26 (62%) of these resulted from American football. Another study reviewed all patients admitted to 1 pediatric trauma service from 1984 to 2000. A total of 193 renal injuries were recorded; 98 (51%) occurred during recreational activities including sports. While 27 occurred during bicycling, only 6 were related to team sports, of which 3 injuries were from American football. Other than 1 reported series of renal injuries in Australian rules football, there are only isolated case reports of sports-related kidney trauma.

There are no published data on the number and consequences of kidney injuries among professional American football players in the National Football League (NFL). This led to the development of this study to examine the number of kidney injuries in the NFL and the effect of these injuries in order to better understand how to guide the management of an athlete with only 1 functioning kidney.

**MATERIALS AND METHODS**

We carried out a retrospective review of the injury registry for the NFL over a 19-year period (1986 to 2004). All cases of reported kidney disorders were reviewed. The type of injury, mechanism of injury, setting of injury (game/practice), player position, player height and weight, treatment, and time to return to play were recorded. Total athlete-exposures during the study period were used to calculate the risk for renal injury in practice compared with during games.

Head physicians and athletic trainers from around the NFL were then surveyed to determine if they were aware of a football player who had lost a kidney due to traumatic kidney injury or suffered loss of kidney function after traumatic kidney injury at the professional, collegiate, or high school level. The survey also asked how they would advise a player with a single functioning kidney at the professional, collegiate, or high school levels (Figure 3).

**RESULTS**

A total of 52 cases of renal injuries were identified from the NFL database, an average of 2.7 cases per season. The overall rate of injury was 0.000012 per exposure, with a significantly higher rate during games (0.000055 per exposure).
than during practice (0.000005 per exposure) \( (P < .0001) \). The most common injury was kidney contusion (42), followed by kidney laceration (6), and kidney stones and dysfunction (2 each) (Figure 4). The median recorded height for the injured players was 6 ft 2 in, median weight was 230.5 lb, and the median body mass index was 29.2. Almost all the injuries were contact related (49), most commonly getting tackled (16) or in a nontackle, nonblocking collision (16). Renal injury was more likely to occur in a game situation (32) compared with practice (20). The distribution of injuries by position was fairly even, with the most injuries occurring among running backs, wide receivers, and defensive secondary (7 each), followed closely by offensive line, defensive line, and linebackers (6 each).

Figure 3. Survey questions administered to National Football League team physicians and athletic trainers.

Are you aware of a football player who has lost a kidney due to traumatic kidney injury at the:

<table>
<thead>
<tr>
<th>Level</th>
<th>No</th>
<th>Yes (please elaborate):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>College</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Are you aware of a football player who has suffered loss of kidney function after traumatic kidney injury at the:

<table>
<thead>
<tr>
<th>Level</th>
<th>No</th>
<th>Yes (please elaborate):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>College</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>No</td>
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</tbody>
</table>

What would you advise a player with a single functioning kidney at the:

<table>
<thead>
<tr>
<th>Level</th>
<th>Don't play</th>
<th>Play (special padding)</th>
<th>Play (normal padding)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College</td>
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<td>High school</td>
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Figure 4. Kidney injuries in the National Football League by year, 1986-2004.
Eighteen of the 52 injured players (34%) required hospitalization for their injury, although none of them required surgery. Players missed the most days after a kidney laceration (mean, 59.8 days; range, 19-111), followed by kidney contusion (mean, 15.1; range, 0-58) and dysfunction (mean, 14.0; range, 4-24). According to the database, no player suffered reinjury to the kidney after return to play.

We received a response to our survey from all 31 other teams in the NFL. One respondent was aware of a professional player who ultimately required a partial nephrectomy. Two teams were aware of a player who had lost a kidney while playing football at the college level and one at the high school level. In terms of advising an athlete with only 1 functioning kidney, 61% of the respondents would allow a professional athlete to play (54% with normal padding, 7% with special padding). By comparison, 51% of respondents would advise a college athlete with only 1 functioning kidney not to play football (5% suggest play with normal padding, 44% with special padding) and 60% would advise a high school athlete with this condition not to play (5% allow play with normal padding; 35% with special padding).

DISCUSSION

Renal trauma is a rare but potentially debilitating injury in professional American football. As might be expected, most of the injuries are contact related. It is not surprising that the athletes face a 10 times greater risk of renal injury during games as opposed to practice conditions. The percentage of injuries occurring during practice is higher than might be expected (~40%), but it results from the much higher number of player-exposures during practices (3.77 million over the study period) as opposed to during games (0.58 million). The players with kidney injuries were not significantly different from the rest of the league in terms of height (NFL median 6 ft 4 in), weight (NFL median 230 lb), or body mass index (NFL median 29.5) over the study period. Approximately one third of the injured players required hospitalization for their injury, and none of the players in this series required surgery. While most players were able to get back to playing within 2 to 3 weeks, players who suffered a severe kidney laceration were likely to miss several months of competition. All the athletes eventually returned to play.

The low rates of surgery and nephrectomy are consistent with previous reports in the literature. The series by Bergqvist et al3 from Sweden reported only 5 cases of surgical intervention, including 2 nephrectomies, in a series of 59 sports-related kidney injuries. The reported series of kidney injuries in Australian rules football only reported on patients who were admitted to the hospital. Among their series of 13 patients, 2 required nephrectomy. The padding used in American football may contribute to the low rate of hospitalization relative to Australian rules football. Although American football players do not typically wear padding around the kidney, the padding worn on the shoulders and other areas may dissipate the force when coming into contact with the trunk and abdomen, perhaps shielding the kidneys.

Successful on-field and postgame management of trauma to the trunk requires, first and foremost, a high degree of suspicion. Because kidney and other intra-abdominal organ injuries are rare, missed or delayed diagnosis can be a problem. When a player presents with significant trauma to the abdomen or back, we adhere to the principles described by Holmes et al. After first assessing airway and breathing, evaluation of hemodynamic status with pulse and blood pressure are mandatory. Hemodynamic compromise from shearing or disruption of major vessels is exceedingly rare but should be ruled out. Next, physical examination should evaluate the presence or absence of costovertebral tenderness, flank mass or ecchymosis, transverse process tenderness, and abdominal rebound tenderness or guarding. The athlete should be evaluated with a screening urinalysis or dipstick of the urine. If gross hematuria is present, a significant renal or bladder injury is suspected and the player should be treated with Foley catheterization and placement of an intravenous line. The player should then be hospitalized; an emergent urologic consultation and CT scan are warranted.

Because microscopic hematuria is common in football players (up to 55% of asymptomatic football players), positive urinalysis does not necessarily indicate significant kidney trauma. Also, it should be noted that the absence of hematuria does not rule out kidney injury. Santucci and McAninch noted that 4% of 2500 patients with traumatic renal injury presented without hematuria. Therefore, we have a low threshold for a complete workup if microscopic hematuria is present or physical examination is positive for significant abdominal or flank trauma. This workup should include a repeat microscopic urinalysis, complete blood count, electrolytes, glucose, amylase, plain radiographs, and a CT scan. Plain radiographs are helpful in diagnosing associated rib fractures and transverse process fractures, and a perinephric hematoma can obscure the psoas shadow. Computed tomography has largely replaced intravenous pyelography in managing renal injury. Computed tomography scans can differentiate between a laceration, hematoma, or contusion and may detect urinary extravasation. Most important, CT can help determine if an injury will require surgical intervention. If a kidney injury is diagnosed, appropriate urologic consultation is obtained. As evidenced by our series of injuries in this report, surgical intervention for kidney trauma in American football is rarely necessary; most kidney injuries are managed with observation, hydration, and analgesics.

Recommendation for return to play after a kidney injury ranges from 2 to 6 weeks. It was clear in our series that most NFL players with renal contusion were able to return to play after approximately 2 weeks. Players with kidney lacerations, however, missed an average of 8 weeks of competition, and some missed the rest of the season. A follow-up urinalysis should be performed before return to play to rule out persistent hematuria. We recommend that physical examination, urinalysis, and laboratory evaluation normalize before returning to play to eliminate the risk of a second hit to a vulnerable, incompletely healed kidney. Also, patients with more severe renal trauma should be reexamined periodically with a urinalysis, blood pressure, and imaging (CT or
intravenous pyelography) to rule out late hydronephrosis or kidney dysfunction such as hypertension.

Because traumatic kidney injuries are rare and unlikely to result in nephrectomy, our data suggest that it is very unlikely for athletes with only 1 functioning kidney to lose their kidney while playing in the NFL. A solitary kidney is either congenital or acquired. The incidence of unilateral renal agenesis is estimated to be 1 in 500 to 1800 people, and this condition is often discovered incidentally. An acquired solitary kidney results from disease or trauma. In the case of trauma, the other kidney is likely to be functional. However, if 1 kidney is lost due to disease, the remaining kidney may be impaired. Athletes with a solitary kidney that is ectopic, multicystic, or functionally impaired or obstructed should avoid contact sports.

The existing literature on the topic of sports participation with a healthy, functioning, solitary kidney has been inconclusive. Generally, the risk of losing a kidney from sports-related trauma is thought to be very low. One study reported that 54% of the members of the American Medical Society of Sports Medicine would allow full sports participation in collision or contact sports at the high school or college level after discussing the possible risks. While this is very similar to the percentage of respondents in our survey who would allow athletes with only 1 kidney to play professional football, it is higher than the percentage of respondents in our survey who would allow such athletes to play at the collegiate or high school level.

A recent study reported that in a survey of the American Society of Pediatric Nephrology, 62% of respondents would not allow participation in contact/collision sports for patients with a single, normal kidney. Eighty-six percent of the respondents who would not allow participation in contact/collision sports identified American football as the primary activity to avoid. However, after reviewing the evidence in the literature, this same study concluded that kidney injury from sports is very rare and that restricting contact/collision sport participation in patients with a single, normal kidney is unwarranted. The findings in our study support that conclusion.

An inherent weakness of this study is the methodology used to classify kidney injuries in the NFL database. The injuries are classified as laceration versus contusion at the discretion of the team physician and athletic trainer. In the medical literature, renal injuries are typically classified by the American Association for the Surgery of Trauma Grading System (AASTGS) (Table 1), with grade I to III injuries usually considered minor and grade IV and V injuries considered major. We suspect that kidney contusion is consistent with grade I to III injuries while kidney laceration correlates to grade IV and V injuries, but with the current methods we cannot confirm this relationship. In the future, more stringent classification of kidney injuries consistent with the AASTGS is advisable for the NFL injury database and should be considered by any other database or study of traumatic kidney injuries.

In summary, traumatic kidney injury is a rare occurrence in professional American football. Athletes are at much greater risk for these injuries during games than during practices. Most injured athletes recover to play but may take some time, especially with a kidney laceration (grade IV and V injury). Athletes with only 1 functioning kidney are unlikely to lose their kidney playing in the NFL. It is not certain that this conclusion can be applied to athletes playing American football at the collegiate and high school level. Nevertheless, this study provides insight into the consequences of traumatic kidney injuries in American football and how to manage kidney injuries in these athletes.

ACKNOWLEDGMENT

The authors acknowledge the work of the NFL athletic trainers in maintaining the NFL database for the past 27 years.

REFERENCES