Reconstruction of the Deltoid-Spring Ligament: Tibiocalcaneonavicular Ligament Complex

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Abstract: Various surgical techniques of deltoid ligament and spring ligament reconstructions in advanced adult-acquired flatfoot deformity have been described. However, none has reported a simultaneous anatomic reconstruction of both the deltoid and spring ligaments. Advanced adult-acquired flatfoot deformity patients often present with combined deltoid and spring ligaments insufficiency, which should be addressed simultaneously to provide adequate correction and maintain static ligamentous stability. We describe a novel anatomic reconstruction of the tibiocalcaneonavicular ligament with peroneus longus allograft. This is the first surgical technique to reconstruct both the deltoid and spring ligament complex.

Level of Evidence: Diagnostic Level 5, expert opinion. See Instructions for Authors for a complete description of levels of evidence.

Key Words: deltoid ligament, spring ligament, calcaneonavicular ligament, flatfoot reconstruction, tibiocalcaneonavicular ligament

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LEARNING OBJECTIVES

After participating in this activity, physicians should be better able to:

(1) Select appropriate patients for reconstruction of the tibiocalcaneonavicular ligament complex.
(2) Implement the surgical technique for reconstruction of the tibiocalcaneonavicular ligament complex.
(3) Educate patients on the risks of the surgical reconstruction of the tibiocalcaneonavicular ligament complex.

HISTORICAL PERSPECTIVE

The spring and deltoid ligaments insufficiency commonly occurs in more advanced stages of the posterior tibial tendon (PTT) dysfunction, known as the adult-acquired flatfoot deformity.[1,2] Dynamic stability of the medial arch is supported by PTT, whereas the static stability is supported by both the spring and deltoid ligaments.[2,3] The spring ligament is the primary restraint to talonavicular deformity, whereas the deltoid ligament provides the main restraint against valgus tilt and external rotation of the talus.[2,3] The integrity of these structures is important in maintaining normal biomechanics of the foot and ankle joint. A previous study demonstrated that restoration of medial column of the foot is not sufficient to take the strain and deforming force upon the ankle when deltoid insufficiency remains.[4]

The superficial deltoid ligament blends with the dorsal part of superomedial spring ligament to provide both medial tibiotalar and talonavicular stability. Recent anatomic study of the deltoid ligament has revealed that the tibiospring ligament, or tibiocalcaneonavicular (TCN) ligament, is one of the most consistently found components of the deltoid ligament.[5] Another study further elucidated that the TCN ligament has the largest total attachment area and provides significant portion of medial stability among other medial collateral and spring ligament complexes.[5]

Although various surgical techniques for the deltoid[2,6–13] and spring ligament[3,14–19] have been published, none has described simultaneous reconstruction of both the deltoid and spring ligaments. The authors believe that combined deltoid and spring ligaments insufficiency should be addressed simultaneously to provide adequate correction and maintain static ligamentous stability in advanced adult-acquired flatfoot deformity. We describe a novel anatomic reconstruction of the TCN ligament with peroneus longus allograft.

INDICATIONS AND CONTRAINDICATIONS

Patients with a passively correctable flatfoot deformity who have failed conservative treatment are appropriate candidates for this procedure. Preoperative tibiotalar valgus tilt should be under 10 degrees as previously noted.[7] A comprehensive medical history and physical examination is undertaken as previously described.[20] We examine gait, standing alignment, foot abduction, Silverskold test, manual muscle testing, single

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FIGURE 1. Mortise x-rays of the ankle. A, Preoperative mortise ankle x-ray. B, Valgus stress view. Widening in medial clear space is noted.

leg heel rise, and ankle stability. Neurovascular examination is also documented.

PREOPERATIVE PLANNING

Weight-bearing films of the foot and ankle (3 views each) are obtained. Ankle valgus stress films are also completed to evaluate mortise asymmetry and medial widening. MRI is also obtained to assess extent of the tibialis posterior tendinopathy, and spring ligament or deltoid ligament tear.

TECHNIQUE

The patient is placed on the operating table in a supine position. Preoperatively, ankle valgus stress examination is performed under fluoroscopy to assess medial laxity (Fig. 1). Extra-articular bony procedures for flatfoot reconstruction are performed as previously described.[21] A medial longitudinal incision is made to expose the PTT. The diseased portion of the PTT is excised and the flexor digitorum longus (FDL) is harvested for transfer. We try to preserve stump of the PTT to facilitate attachment of the FDL transfer. The FDL is identified at the Knot of Henry and 2-0 Ethibond suture is used for tenodesis of the flexor hallucis longus and FDL. The FDL is then transected proximal to the tenodesis and No. 2 Looped FiberWire (Arthrex, Naples) is placed in the distal FDL stump for the transfer to the navicular. The medial static ligament complex is exposed and examined. Tears in the spring ligament are repaired and imbricated (Fig. 2). Bone tunnels are drilled in the navicula, distal tibia, and sustentaculum

FIGURE 2. The spring ligament complex proximal to the talonavicular joint capsule is shown. A large tear and attenuation in the ligament is illustrated.

FIGURE 3. Illustration of the bone tunnel locations in the distal tibia, navicular, and sustentaculum tali.

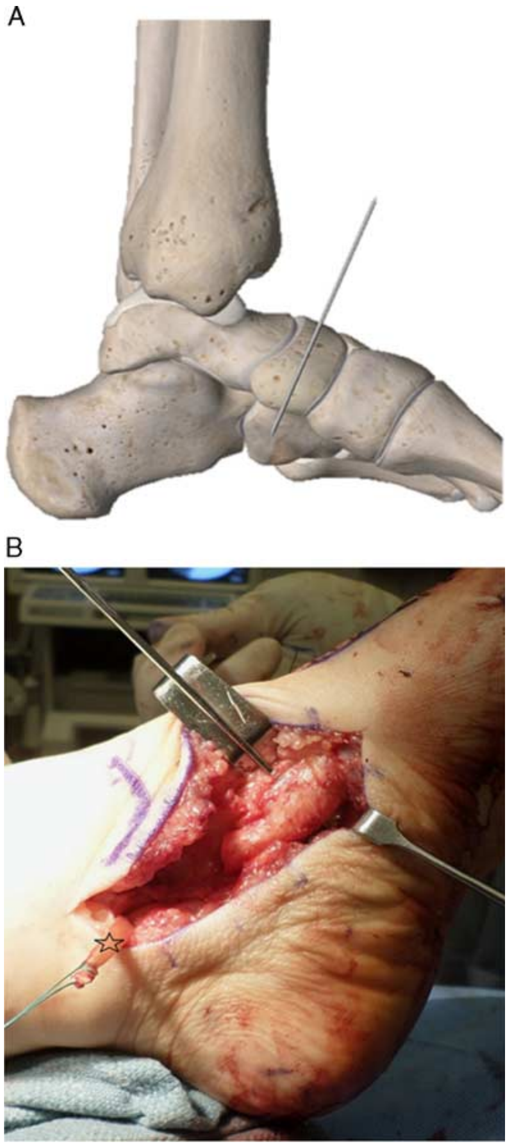

FIGURE 4. Navicular bone tunnel. A, Illustration of the navicular bone tunnel with guidewire placement from dorsal to plantar. B, Intraoperative photograph of the navicular bone tunnel with guidewire placement from dorsal to plantar. The harvested FDL tendon (asterisk) with FiberWire stitch is shown on bottom left.

tali, based on the anatomic foot prints of the tibionavicular, tibiospring, inferior calcaneonavicular, and tibiocalcaneal ligaments[22] (Fig. 3).

Navicular Bone Tunnel

Guidewire is inserted through the navicular tuberosity in a dorsal to plantar direction. Starting point for bone tunnel is close to the medial edge while leaving an adequate bone bridge to avoid "blow out" of the bone. A 6 mm cannulated drill bit is then used over the guidewire (Figs. 4A, B)

Preparation of the Allograft

The peroneus longus and semitendinosus allograft have been utilized by the authors. We found that peroneus longus tendon is more consistent in diameter than the semitendinosus

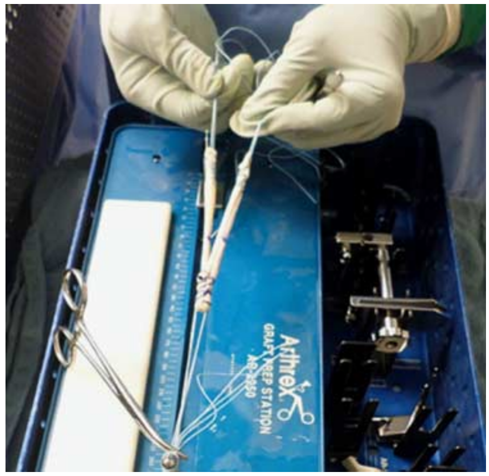

FIGURE 5. Illustration of the graft preparation.

allograft. The total length of the allograft should be close to 25 cm and diameter of 6 mm. The allograft tendon is folded in half to create 2 limbs. Approximately 2 cm of the folded portion of the allograft is trimmed to allow easy passage through 7 mm diameter sizer. No. 2 Looped FiberWire (Arthrex) is placed in the folded portion of the graft. No. 2 Looped FiberWire is also placed in the distal 4 cm portion of the each graft limb (Fig. 5).

FIGURE 6. Illustration of the tibial bone tunnel. Guidepin inserted from anterior aspect of the intercolliculus of medial malleolus.

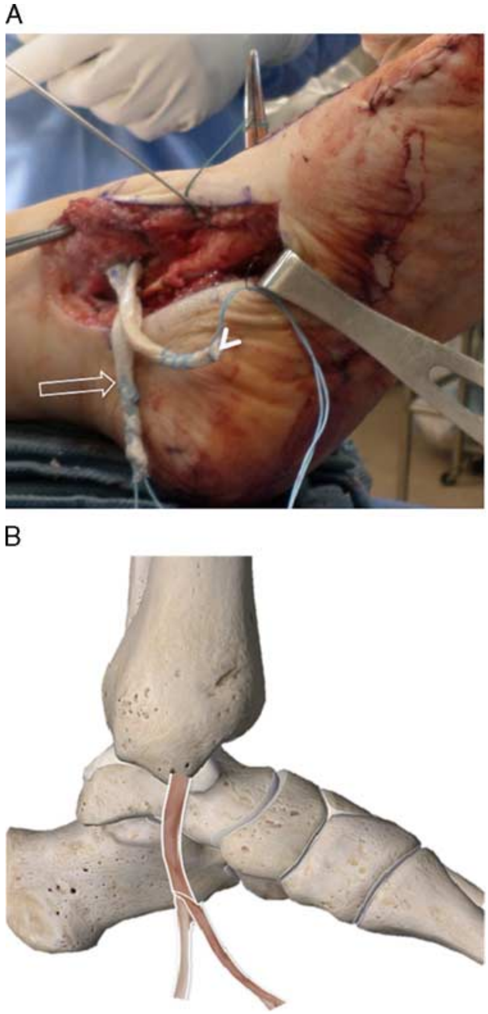

FIGURE 7. A, Two limbs of tendon are shown. The graft has been placed through tibial tunnel. The navicular limb has been passed into navicular tunnel from plantar to dorsal direction (arrowhead). The calcaneal limb is visible, and has not been passed into tunnel yet (arrow). B, Illustration of allograft with 2 limbs, calcaneal and navicular, respectively.

Medial Malleolar Bone Tunnel

The intercolliculus of the medial malleolus is exposed. A vertical bone tunnel is made, and a guidewire is inserted at the anterior portion of the intercolliculus and aimed in a vertical manner toward the medial side of the distal tibia (Figs. 6, 7). Central position of the guidewire within medial malleolus is confirmed by fluoroscopic imaging to avoid violating the medial gutter of the ankle joint. A 2 cm incision is made over the medial distal tibia to expose the guidewire. A 7 mm cannulated drill bit is drilled over the guidewire to create the tibial bone tunnel. The folded portion of allograft is passed through the medial malleolar tunnel to the 2 cm mark. While graft tension is maintained by pulling in both a proximal and distal direction, 4.75 mm Biocomposite Tenodesis screw (Arthrex) is placed through the distal part of the tibial tunnel for fixation. At the end of the procedure, the tibial tunnel graft is post tied to the medial distal tibia shaft with a 3.5 mm cortical screw and washer. A 2.5 mm drill bit is utilized to drill a bicortical tunnel into the distal tibia shaft, approximately 3 cm proximal to the tibial tunnel. A

FIGURE 8. Guidewire placement through calcaneal tunnel at sustentaculum tali.

depth gauge is then used for measurement, and a 3.5 mm cortical screw with washer is inserted, but not fully tightened.

The No. 2 FiberWire looped stitches placed at the folded end of the graft (tibial limb) is retrieved out of the tibial tunnel and tied to the 3.5 mm cortical screw and washer. The screw is then fully tightened over the washer.

Sustentaculum Tali Tunnel

Sustentaculum tali is exposed while protecting the neurovascular bundle. The FHL runs underneath the sustentaculum tali and can be used as a landmark for tunnel placement. The tibial nerve should be identified and protected by retracting inferiorly with the FHL. Guidewire is inserted 1 mm inferior to sustentaculum tali, aiming 20 degrees plantarly, away from subtalar joint (Fig. 8). A 1 cm skin incision is made over the exiting guidewire and then drilled bicortically with a 6.0 mm drill bit. Care should be taken to avoid injury to the subtalar joint, tibial nerve on the medial side, and peroneal tendon and sural nerve on the lateral side as guidewire and cannulated drill are passed.

Graft Tensioning

One limb of the allograft is passed through navicular in a dorsal to plantar direction (Figs. 9A, B), whereas the other limb is passed through the calcaneal tunnel (Fig. 10). The FDL tendon is then passed through the navicular tunnel, also in a plantar to dorsal direction. FDL tendon should be placed superior to the allograft to preserve its excursion (Fig. 11). The navicular limb of the allograft is tensioned together with transferred FDL tendon, while holding the hindfoot in varus and transverse joint in adduction (Fig. 12). Tendons are maximally pulled and released. Final tension should be halfway between maximal and minimal tension to maintain excursion of the FDL tendon. We try to put slightly less tension on the allograft and confirm excursion of the FDL with preservation of talonavicular joint motion before fixing with 5.5 mm Biocomposite Tenodesis screw (Arthrex) inserted in dorsal to plantar direction. The calcaneal limb of the allograft is passed through the sustentaculum tali tunnel and pulled out of the lateral aspect of the heel. While maintaining laterally directed tension by pulling on the FiberWire suture exiting the lateral calcaneus, 5.5 mm Biocomposite Tenodesis screw (Arthrex) is placed for fixation (Fig. 13). The FDL tendon is sutured to stump of the PTT.

EARLY CLINICAL RESULTS

A total of 3 patients with concurrent PTT dysfunction and spring ligament tears have been treated with the technique described. Our preliminary clinical results have been very encouraging with improved patient-reported pain score,

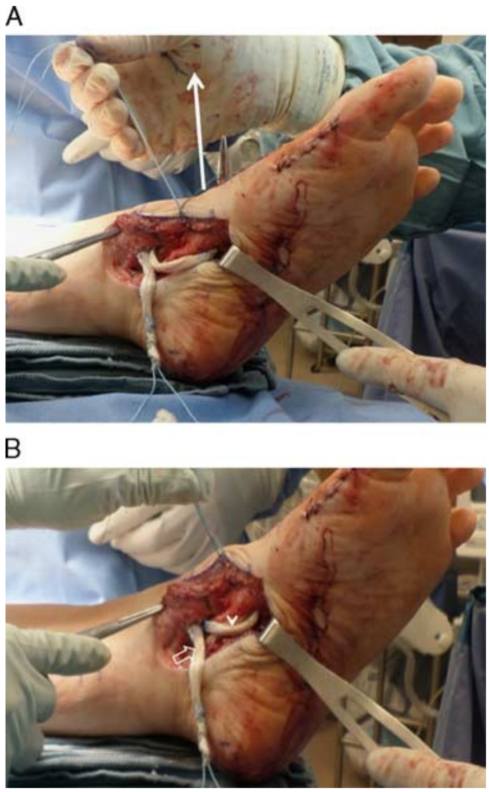

FIGURE 9. A, The navicular limb has been passed into navicular tunnel from plantar to dorsal direction. Direction of tension on the FiberWire suture by assistant (arrow). B, The navicular limb (arrowhead) has now been fully passed into navicular tunnel from plantar to dorsal direction. The calcaneal limb is visible, and has not been passed into tunnel yet (arrow).

maintenance of transverse tarsal joint motion, and restoration of neutral alignment of the ankle and talonavicular joint in all 3 patients. Postoperative weight-bearing films have shown maintenance of deformity correction. We are continuing to collect long-term clinical and patient-reported outcome measures and radiographs.

FIGURE 10. The diameter of the calcaneal limb (arrow) has been measured and guidewire has been inserted into the calcaneal tunnel at the sustentaculum tali.

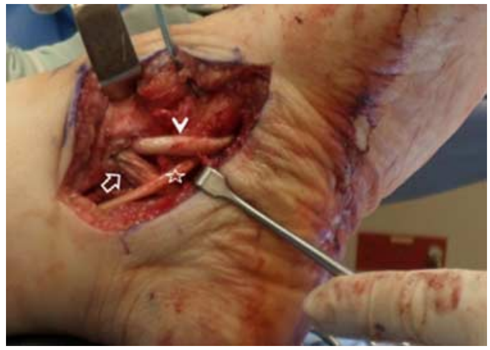

FIGURE 11. Graft and FDL tendon pretensioning: The calcaneal and navicular limbs have been passed through their respective tunnels. The FDL tendon (*) has been passed through the navicular tunnel. Tensioning has not been undertaken. The navicular graft limb (arrowhead) and tibiocalcaneal limb (arrow) are also shown.

COMPLICATIONS

Risks of the approach include possible injury to the tibial nerve and posterior tibial artery during exposure of the sustentaculum tali. Meticulous dissection, identification of the neurovascular bundle, and protection of it during drilling is needed. On the lateral side of the tunnel, the peroneal tendons and sural nerve are at risk during passing of the guidewire and cannulated drill. When creating the sustentaculum tali tunnel, additional care should be taken not to violate the LCL and MCO osteotomy sites and not to compromise their fixations.

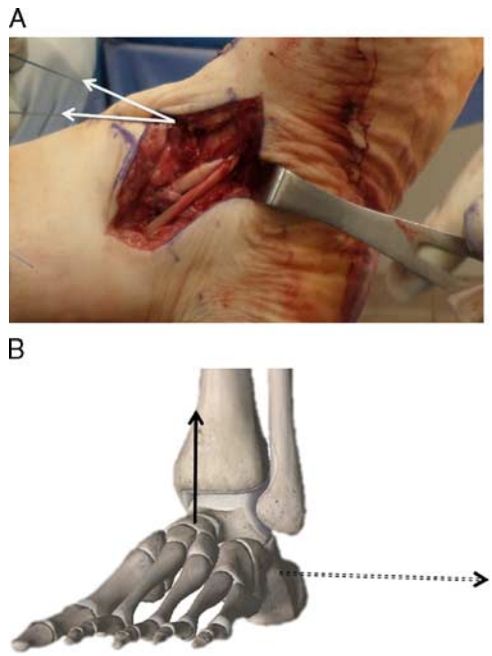

FIGURE 12. Graft tensioning. A, Graft and FDL tendon during tensioning. Direction of tensioning on FiberWire suture for the navicular limb and FDL tendon shown by long arrow. B, Schematic illustration of graft tensioning in coronal plane. Navicular allograft limb and FDL tendon tensioning (solid arrow). Direction of tensioning of the calcaneal limb in a lateral direction (dashed arrow).

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FIGURE 13. The navicular graft limb (arrowhead) and FDL tendon (asterisk) has been tensioned and biotenodesis screw inserted into navicular for fixation. Appropriate graft tension is probed with instrument placed under tibiocalcaneal limb (arrow).

POSTOPERATIVE MANAGEMENT

Patients are immobilized in short-leg splint for 2 weeks until sutures are removed. Then, non–weight-bearing short-leg cast is applied for 4 weeks. Patients are transitioned to fracture boot at 6 weeks and begin active range of motion exercises and strengthening. Gradual weight-bearing resumes at 8 weeks, with aim of full weight-bearing at 10 weeks. At 12 weeks, patients are transitioned to regular shoe wear and gradually return to previous activities.

DISCUSSION

To the best of our knowledge, this is the first surgical technique to reconstruct both deltoid ligament and spring ligament complex.

The technique proposed has several advantages over previous reconstructions. Our bone tunnel placement is based on the anatomic attachment sites of the spring (calcaneonavicular) ligament, tibionavicular, and tibiocalcaneal ligament.[22] In addition, the use of a forked allograft between the tibia, calcaneus, and navicular allows anatomic reconstruction of the tibiospring ligament. This is one of the most constant components of the superficial deltoid ligament, along with the tibionavicular ligament.[22] Both of these ligaments are reconstructed through this technique. Tibionavicular ligament has been found to provide coronal stability and provides a restraint to hindfoot eversion.[23] Failure to recreate the tibionavicular ligament may have led to deltoid ligament reconstruction failures.[7] The authors previously noted postoperative progression of ankle valgus tilt and medial instability following triple arthrodesis and deltoid reconstruction by another technique.

Our technique has successfully restored tibiotalar stability in response to valgus stress conducted preoperatively and postoperatively under fluoroscopy.

In conclusion, this technique is the first to incorporate anatomic reconstruction of the TCN ligament complex, which includes both the deltoid ligament complex and spring ligament, and offers surgeons a more stable and anatomic reconstruction option.

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CME QUESTIONS

(1) What type of patient may be a good candidate for reconstruction of the tibiocalcaneonavicular ligament complex?

A. Adult patients with flexible or rigid flatfoot deformity.
B. Adult patients with flexible flatfoot deformity.
C. Pediatric patients with flexible flatfoot deformity.
D. Adult patients with stage 4 flatfoot deformity.

(2) What is the primary function of the spring ligament?

A. Primary restraint to ankle valgus tilt.
B. Primary restraint to talonavicular deformity.
C. Primary restraint to ankle varus tilt.
D. Primary restraint to external rotation of the talus.

(3) What procedure is combined with reconstruction of the tibiocalcaneonavicular ligament complex?

A. FHL transfer.
B. FDL transfer.
C. Peroneus longus transfer.
D. Peroneus brevis transfer.

(4) What preoperative or intraoperative study is recommended prior to reconstruction of the tibiocalcaneonavicular ligament complex?

A. CT scanogram (full length, bilateral lower extremity).
B. MRI of ankle and foot (without contrast).
C. EMG and nerve conduction studies.
D. Valgus stress test of ankle.

(5) Which of the following structures is at risk during reconstruction of the tibiocalcaneonavicular ligament complex?

A. Deep peroneal nerve.
B. Posterior tibial artery.
C. Saphenous vein and nerve.
D. Anterior tibial artery.

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ANSWER SHEET FOR TECHNIQUES IN FOOT & ANKLE SURGERY
CME PROGRAM EXAM
March 2016

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Your completion of this activity includes evaluating it. Please respond to the following questions below.

Please rate these activities (1 — minimally, 5 — completely)	1 2 3 4 5
This activity was effective in meeting the educational objectives	O O O O O
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This activity was relevant to my practice	O O O O O

Please rate your ability to achieve the following objectives, both before this activity and after it: 1 (minimally) to 5 (completely)	Pre 1 2 3 4 5	Post 1 2 3 4 5
Select appropriate patients for reconstruction of the Tibiocalcaneonavicular ligament complex	O O O O O	O O O O O
Implement the surgical technique for reconstruction of the Tibiocalcaneonavicular ligament complex	O O O O O	O O O O O
Educate patients on the risks of the surgical reconstruction of the Tibiocalcaneonavicular ligament complex	O O O O O	O O O O O

How many of your patients are likely to be impacted by what you learned from this activity?
O <20% O 20-40% O 40-60% O 60-80% O >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 — definitely will not change, 5 — definitely will change)	1 2 3 4 5
	O O O O O

How will you apply what you learned from these activities (mark all that apply):

In diagnosing patients O	In making treatment decisions O
In monitoring patients O	As a foundation to learn more O
In educating students and colleagues O	In educating patients and their caregivers O
As part of a quality or performance improvement project O	To confirm current practice O
For maintenance of board certification O	For maintenance of licensure O

Please list at least one strategy you learned from this activity that you will apply in practice:

____

How committed are you to applying these activities to your practice in the ways you indicated above? (1 — minimally, 5 — completely)	1 2 3 4 5
	O O O O O

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