In 2009, the United Kingdom National Cataract Dataset of 55,567 cases reported overall posterior capsular rupture or vitreous loss rates of 1.92%.\(^1\) The British Ophthalmological Surveillance Unit (BOSU) reported 610 nuclear fragments displaced into the vitreous during 1 year in the United Kingdom, which is an incidence of between two and three per 1,000 operations, or approximately 0.3%.\(^2\) Although the frequencies of these are low, the complications of a dropped nucleus or vitreous loss may include raised intraocular pressure (IOP), uveitis, corneal edema, cystoid macular edema, and retinal detachment. When managed properly, however, the risk of further complications can be minimized, and the results can be as good as if it had never happened. This is reflected in the fact that two-thirds of all patients with a dropped nucleus between 2003 and 2004 had a final corrected vision of 6/12 or better.\(^3\)

**RISK FACTORS**

The many publications investigating risk factors associated with posterior capsule rupture and vitreous loss have allowed surgeons to more accurately predict complications prior to surgery, plan more effectively, and counsel patients who are at risk.\(^1\)

Early recognition of posterior capsular rupture or zonule dehiscence is key to preventing further problems as surgery progresses; it allows the surgeon to try to avoid certain maneuvers that can upset a precariously perched nucleus. Robert Osher, MD, carried out a series of experiments on cadaveric eyes to better understand what role vitreous contributes to the nucleus drifting downward.\(^4\) His findings suggest that in most cases the nucleus will sit supported by the vitreous if undisturbed. Older vitreous with more syneresis, however, will allow easier passage of the nucleus into the posterior segment. He also noted that high infusion pressures and pressure gradients have little bearing on the behavior of the nucleus, as the pressure is equal across the whole eye. The effect of high aspiration and post-occlusion surge due to high vacuum settings, however, can easily pull the vitreous supporting the nucleus toward the phaco tip, allowing the nucleus to drop. He also identified the turbulence created by phacoemulsification as a contributing factor in shifting vitreous support.

**ANTERIOR VITREOUS REMOVAL**

It is important to note that the underlying principle of complication management in any surgical setting must be to reduce the risk of further complications. Although the nucleus may sit on the vitreous, it may not be safe to deal with it in that position, as surgical
maneuvers disrupt vitreous or cause retinal traction, increasing the risk of retinal complications. We therefore present a straightforward didactic plan for dealing with posterior capsular rupture and/or vitreous loss, together with an algorithm for handling dropped nuclear fragments and a view of how the two surgical teams, anterior and posterior, should proceed.

The primary goal for the surgeon following early posterior capsular rupture or zonular dehiscence is to remove as much of the remaining nucleus as possible, but not without considering the risks that this involves.

The most important intraoperative risk factor is vitreous traction. Continued irrigation alone following posterior capsular rupture is unlikely to cause the nucleus to drop, as demonstrated by Dr. Osher. Rather, it allows time to reassess the situation, move the nuclear fragments to a safe position if possible, and then remove the second instrument. An ophthalmic viscosurgical device (OVD), preferably dispersive, can then be injected to coat and tamponade the vitreous while also supporting the nucleus, allowing the phaco needle to be withdrawn without letting the vitreous surge forward toward the wound. This acts as a “freeze-frame,” allowing one to assess the situation and plan further strategies. Performing bimanual vitrectomy through two paracenteses with a low bottle height and high cut rate, the surgeon can then remove vitreous, using triamcinolone acetonide for visualization (Figure 1A). This allows further surgical maneuvers to be performed in a vitreous-free environment, reducing or eliminating vitreous traction. Because all vitreous in the anterior chamber must be removed, it is usually a good idea to debulk the anterior vitreous from behind the posterior capsule to discourage the vitreous from prolapsing forward during further maneuvers. Teixeira et al.5 examined the effects of vitrectomy on retinal traction through a pars plana approach in vitro and found that traction is directly related to the vacuum and inversely related to the cut rate and distance from the retina; these principles can be applied to anterior vitrectomy. The settings should therefore be low vacuum (100 mm Hg to 150 mm Hg) and the highest cut rate possible.

Once the anterior chamber is vitreous-free, it is usually advisable to pass the cutter through the opening in the posterior capsule and continue to remove a generous amount of anterior vitreous (Figure 1B). This step should be performed carefully—it is not unusual for this to take several minutes. Residual soft lens matter can then be removed using the vitrector in aspiration mode (Figure 1C). If no nuclear fragments have descended into the posterior vitreous and the anterior capsulorrhexis is intact, a sulcus lens can be placed with optic capture (Figure 1D).

Figure 1. Triamcinolone is instilled into the anterior chamber on suspecting vitreous loss (A). Bimanual anterior vitrectomy through two paracentesis incisions (B). Following complete clearance of vitreous, the vitrector is used in aspiration-only mode to remove remaining lens matter (C). IOL is placed in the sulcus, and then the optic is positioned behind the capsulorrhexis to achieve optic capture of the three-piece lens (D).
CONSIDERATIONS FOR NUCLEAR MATERIAL REMOVAL

For safe nuclear material removal, the cutting rate should be dropped. In the case of a dense nucleus, an alternative strategy is to enlarge the wound and remove nuclear fragments directly. It is dangerous to continue to phaco (ultrasound plus vacuum/aspiration) in the presence of vitreous in order to remove nuclear fragments at this stage. The phaco tip cannot cut vitreous gel and would instead aspirate, leading to vitreoretinal traction via the vitreous base and creating a high risk of retinal tear.

An alternative approach is to use a dry technique, in which vitreous is cut and removed without infusion. This is called dry anterior vitrectomy and is particularly useful for small amounts of vitreous presenting toward the end of a procedure (eg, if a strand of vitreous presents through a small area of zonular loss toward the end of cortical cleanup or after IOL implantation). In this situa-

Figure 2. Dry anterior vitrectomy. Vitreous strand presents through zonule at 9 o’clock position toward the end of cortical cleanup (green arrows). This is tamponaded by OVD, and most of the cortex is removed without disturbing this limited amount of presenting vitreous (A). After IOL implantation in the bag, the cutter is used to remove the vitreous strand in a OVD-filled anterior chamber without infusion (B).

Figure 3. Lens matter in the posterior segment along with a giant retinal tear. When the nucleus displaced, the referring surgeon tried to chase it with the phaco tip, and resulting traction probably caused the giant tear (A). As perfluorocarbon (PFCL) liquid is used to flatten the retina, a linear retinal tear extending almost up to the optic disc is also seen, which is along the probable line of the phaco probe approach (B).
tion, the most efficient method is to refill the anterior chamber with an OVD and cut and remove the strand of vitreous with the cutter (Figure 2), topping up the OVD into the anterior chamber to avoid anterior chamber col-

lace. Because minimal maneuvering is required—and only a small volume removed—the anterior chamber will not collapse, and the surgical goal is rapidly achieved. A dispersive OVD that will tamponade the vitreous is pre-

ferred in this setting. If the nucleus has drifted out of reach, an attempt at retrieval via the anterior chamber is ill-advised. Rather, we recommend clearing the anterior vitreous and converting to pars plana vitrectomy (PPV). In cases managed by an anterior segment surgeon who lacks the experience and equipment, the eye should be closed and the patient referred to a vitreoretinal surgeon.

The question of whether to implant an IOL at the time of nucleus drop if no PPV is undertaken is contentious. The BOSU data suggest that of all IOLs inserted at the time of cataract surgery, 77% were removed or replaced upon subsequent PPV. It is best, therefore, if anterior and posterior segment surgeons practice comanagement and agree upon whether an IOL should be implanted if no PPV is to be performed. Most vitreoretinal surgeons currently agree that placement of a secure IOL at time of primary surgery is advisable as long as it is stable. With an intact capsulorrhexis, a three-piece IOL can be placed using optic capture with the haptics in the sulcus but the optic behind the capsulorrhexis, resulting in a stable IOL position. A one-piece IOL should not be used in this situation. Anterior chamber IOLs should be avoided at the time of primary surgery in the presence of a displaced nuclear fragment; however, they may be an option at the time of PPV or at a later date in the absence of sufficient capsular support.

If a nuclear fragment has dropped into the posterior segment, the anterior segment surgeon should make no attempt to pursue it (Figure 3). Once the anterior segment has been cleared, it is important to manage inflammation and any rise in IOP with appropriate medication. A full explanation should be made to the patient, emphasizing that although a complication has occurred, a good outcome is still likely, with appropriate further surgery undertaken by the vitreoretinal team. Although this is not an emergent situation, prompt contact between the cataract and vitreoretinal surgeon is essential; the outcomes of vitrectomy with removal of nuclear fragments within 1 week are favorable; a more prompt procedure is likely to provide the best out-

comes. In high-risk situations, such as unstable traumati-
cataacts and posterior polar cataracts, where the risk of posterior capsular rupture and nucleus displacement is significant, it may best the vitreoretinal surgeon see the patient preoperatively. This drives home the importance of potential complications and emphasizes that good pathways for professional collaboration are in place to deal with any complications that may occur.

**Pars Plana Vitrectomy**

The underlying principle of PPV for displaced nuclear fragments is to perform a complete vitrectomy, including removal of vitreous base as far as possible, employing a standard three-port pars plana approach (Figure 4A) with a conventional 20-gauge system or a smaller-gauge suture-
less system (23 or 25 gauge). There are limited data available on the use of small-gauge instrumentation for lens fragment removal, but initial reports of outcomes with 25-gauge PPV without the use of a fragmatome are similar to those with 20-gauge instrumentation. There are also
reports of 23- and 25-gauge instrumentation combined with a fragmatome in a mix-and-match approach, using a local peritomy and a single enlarged port. The advantages of the mix-and-match approach include having only one incision to suture at the end of a case, and performing faster surgery, and speeding postoperative healing.9

Smaller-gauge vitrectomy systems require high infusion pressures and high flow rates to meet the demand of the aspiration through the wider-bore fragmatome, which might lead to more vitreous traction and intraoperative hypotony. A fragmatome, which is similar to a phaco probe without an infusion sleeve, cannot cut vitreous, so a complete vitrectomy must be performed prior to introducing the fragmatome to the eye. This can be aided by triamcinolone staining, particularly if visibility is limited. Also, because there is no counter-resistance by the capsular bag, it is essential to use a pulse or micropulse setting on the fragmatome, with low to moderate vacuum, to avoid bouncing the nuclear fragments around the vitreous cavity due to the repulsion caused by ultrasound energy (Figure 4C).

Perfluorocarbon liquid (PFCL) can be used to cover the macula and float the nucleus away from the retina prior to engaging the fragment with either the vitrector or the fragmatome (Figure 4B). This helps to protect the macula during removal of the lens fragments in the mid-vitreous cavity. Prior to closure, it is important to remove all PFCL and to carefully inspect for residual fragments and iatrogenic retinal tears. It is particularly important to inspect the vitreous base, as tiny retinal breaks close to the ora serrata are easy to miss but can cause subsequent retinal detachments (Figure 4D). A common misconception among anterior segment surgeons is that PFCL is used to float the nucleus into the anterior chamber from where it can be extracted through a limbal or corneal incision. In fact, the majority of displaced nucleus fragments can be dealt with safely in the posterior segment, with the PFCL acting only as a cushion to the macula while nuclear fragments are addressed with the fragmatome.

SUMMARY

It is essential to keep potential future complications in mind when dealing with a perioperative complication. In the case of vitreous loss or loss of nuclear fragments at the time of surgery, a careful anterior vitrectomy technique (using triamcinolone and avoiding vitreoretinal traction) and PPV can result in an excellent outcome. ■

Craig K. Parkes, MD, is with the Wirral University Teaching Hospital NHS Foundation Trust, Spire Murrayfield Hospital, in Wirral, United Kingdom. Dr. Parkes states that he has no financial relationships relevant to the products or companies discussed in this article. He can be reached via e-mail at ckiparkes@hotmail.com.

Manish Nagpal, MS, DO, FRCS(UK), is Senior Consultant, Retina & Vitreous Services, at the Retina Foundation & Eye Research Centre in Gujarat, India. He is a Retina Today Editorial Board Member. Dr. Nagpal states that he has no financial relationships relevant to the products or companies discussed in this article. He may be reached at +91 79 22865537; or via e-mail at drmanishnagpal@yahoo.com.

Brian Little, MA, FRCS, FRCOphth, is a Consultant Surgeon at Moorfields Eye Hospital in London. Dr. Little states that he has no financial relationships relevant to the products or companies discussed in this article. He can be reached via e-mail at brianlittle@blueyonder.co.uk.

Som Prasad, MS, FRCSed, FRCOphth, FACS, is a Consultant Ophthalmologist at the Wirral University Teaching Hospital NHS Foundation Trust & Spire Murrayfield Hospital. He reports that he is a consultant for Bausch +Lomb (UK). Dr. Prasad states that he has no financial relationships relevant to the products or companies discussed in this article. He can be reached at +44 151 6047193; fax: +44 151 9098091; or via e-mail at sprasad@rcsed.ac.uk.