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Recurrence Mechanisms and Preventive Strategies for Wrist Ganglion Cysts

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Abstract:

Wrist ganglion cysts are one of the most prevalent benign cystic lesions of the hand, with high recurrence rates posing a significant clinical challenge. Research indicates that recurrence is frequently linked to incomplete excision of the cyst pedicle, untreated one-way valve mechanisms connecting to the joint cavity, and abnormalities in local joint fluid dynamics, such as increased intra-articular pressure. Additionally, histological changes, including abnormal fibroblast proliferation and excessive hyaluronic acid accumulation, are also critical factors contributing to recurrence. Although aspiration is minimally invasive and well-tolerated by patients, it carries a high recurrence rate. In contrast, open and arthroscopic excision allow for better identification and removal of the cyst pedicle, yet recurrence rates still range from approximately 10% to 30%.In recent years, imaging has played an increasingly important role in preoperative planning. High-resolution MRI and ultrasound can enable surgeons identify the origin of the cyst pedicle. Minimally invasive alternatives such as platelet-rich plasma (PRP) injection and needle fenestration have demonstrated high safety and low recurrence potential. Moreover, arthroscopic excision under direct visualization, combined with local thermal ablation or tissue barrier repair, has been shown to further reduce recurrence. Postoperative management, particularly the balance between immobilization duration and early functional rehabilitation, is also critical in minimizing recurrence. This review aims to systematically summarize the recurrence mechanisms and major treatment strategies for wrist ganglion cysts and to explore the clinical prospects of emerging therapeutic interventions.

Keywords: Ganglion cyst; recurrence mechanism; minimally invasive surgery; biological therapy; preventive strategy.

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1. Introduction

Wrist ganglion cysts are among the most common benign cystic lesions encountered in clinical practice, accounting for approximately 60% to 70% of soft tissue masses of the hand and wrist. Although ganglion cysts can occur at any age, they are most frequently seen in women aged 20 to 50 years [1]. Clinically, they present as cystic swellings on the dorsal or volar aspect of the wrist, with some patients experiencing aching or pain, and in severe cases, restricted movement or impaired quality of life and work performance. Epidemiological and natural history studies have shown that many cysts may spontaneously shrink or resolve. For example, cysts located on the hand, with mild symptoms and no significant pain or functional impairment, have a relatively high spontaneous resolution rate, especially there are no imaging indications of nerve compression or muscle atrophy. However, symptomatic or functionally limiting cases require intervention. The pathogenesis of ganglion cysts remains controversial, with the main theories including the synovial fluid one-way valve mechanism, mucinous degeneration theory, and repetitive microtrauma theory. Collectively, these hypotheses suggest that ganglion cysts may originate from structural abnormalities of the joint or tendon sheath, or be associated with local degenerative changes and mechanical stress [2].

Traditional treatment options for wrist ganglion cysts range from conservative observation and splint immobilization to aspiration, injection therapy, and open or arthroscopic excision. Conservative or minimally invasive approaches cause less trauma but are associated with a high recurrence rate, whereas open or arthroscopic excision offers lower recurrence rates but carries risks such as scarring and joint stiffness. Moreover, recurrence or the need for reoperation may still occur if surgical techniques are suboptimal or the cyst pedicle is incompletely excised. Studies have shown that the recurrence rate following aspiration is significantly higher than that after surgical excision. However, reported recurrence rates after surgery vary widely among studies, with surgeon experience, residual cyst pedicle, and anatomical location of the lesion identified as key contributing factors [3].

With advances in imaging and minimally invasive technology, high-resolution ultrasound and MRI have become valuable tools for preoperative localization of the cyst pedicle and for assessing its communication with the joint or tendon sheath [4]. These imaging modalities can assist in selecting more precise treatment strategies and reducing residual lesions. Artificial intelligence–based imaging analysis is still in the exploratory stage but holds promise for improving the detection rate of small or occult lesions. Meanwhile, novel minimally invasive modalities such as radiofrequency ablation, laser therapy, and other thermal or energy-based techniques, as well as biomaterial-based barrier and repair strategies, have been proposed to reduce recurrence [5]. However, most of the available evidence comes from case reports or small-sample studies, with limited long-term follow-up data and insufficient safety evaluation. Therefore, more high-quality longitudinal studies are needed to validate their efficacy and safety. This review aims to systematically summarize the recurrence mechanisms and associated risk factors of wrist ganglion cysts, evaluate the recurrence risks of current treatment methods, and explore the application prospects of emerging diagnostic and interventional strategies, with the goal of providing evidence-based guidance for individualized treatment and prevention.

2. Pathogenesis and Recurrence Factors

2.1 Residual Pedicle and Anatomical Basis

The recurrence of ganglion cysts is not a spontaneous formation of a new, independent cystic structure. Instead, it results from the complex interaction of anatomical, biological, and mechanical factors. Ganglion cysts typically originate from either the joint capsule or tendon sheath, with a narrow stalk or channel linking the cyst to these structures. This stalk serves as both the pathway for the continuous supply of synovial fluid and the anatomical foundation for potential recurrence. This connection not only provides a continuous source of synovial fluid but also serves as the anatomical basis for potential recurrence.

Residual cyst pedicle is widely recognized as the primary mechanism of recurrence. If surgery removes only the visible cyst without completely excising or sealing the stalk connecting it to the joint or tendon sheath, the remaining root can serve as a source of fluid leakage and accumulation, which may lead to the formation of a new cystic cavity and subsequent clinical recurrence. Pathological and imaging findings in recurrent cases often reveal residual communicating channels or overlooked pedicles.

Comparatively, open excision allows for better direct visualization of the cyst pedicle and surrounding tissue, which helps achieve a more thorough removal, reducing the risk of recurrence. In contrast, minimally invasive techniques, such as aspiration, often leave the cyst stalk intact or insufficiently excised, which results in a higher recurrence rate. Statistical data show that complete exci-

sion of the cyst, including the pedicle and a portion of the joint capsule or ligament, via open or arthroscopic surgery results in a significantly lower recurrence rate than simple cyst removal or aspiration [6]. Surgical experience and technique, such as whether the pedicle is removed and whether arthroscopic repair is performed, are strongly correlated with recurrence rate, with experienced surgeons achieving markedly lower recurrence. A recent case report also demonstrated that cysts located in specific regions, such as intratendinous or deep-seated areas, are more difficult to excise completely, which increases the risk of recurrence [7].

2.2 One-Way Valve Mechanism

During joint movement, synovial fluid is forced into the cyst cavity through a cap-like or narrow channel, while a valve-like structure prevents the fluid from flowing back into the joint cavity. This one-way mechanism leads to continuous accumulation of fluid within the cyst and gradual expansion of its volume. Imaging modalities such as ultrasound and MRI, as well as intraoperative observations, often reveal a narrow stalk or small opening between the cyst and the joint capsule, supporting the existence of such a mechanical channel. This mechanism explains why recurrence may occur even after aspiration or partial excision of the main cyst if the channel and valve-like structure are not completely eliminated, as synovial fluid can continue to flow into the cyst cavity from the joint space [8]. Similar one-way fluid flow mechanisms have also been observed in certain cystic lesions around the knee or along the spine, suggesting that this principle may represent a common pathogenic process across synovial cysts in different anatomical locations. Surgical management of the valve-like structure, such as adequate exposure and repair of the joint capsule opening during cyst excision, is considered a key technical step in reducing recurrence [9].

2.3 Histological Changes and Mucoid Degeneration

Histological analyses show that the wall of a ganglion or mucous cyst is typically composed of sparsely cellular, collagen-rich connective tissue, while the cystic contents are rich in hyaluronic acid and other mucopolysaccharides. The continuous production of these mucinous substances is thought to be associated with fibroblast activation and abnormal extracellular matrix metabolism. Two major hypotheses have been advanced to explain the origin of ganglion cysts, reflecting distinct yet complementary biological processes. One perspective attributes cyst development to focal herniation of the synovial lining, where joint fluid is gradually displaced beyond the capsule through a weakened area of the membrane. The alternative view emphasizes the role of extracellular matrix degeneration, in which mucin-rich droplets accumulate within the periarticular connective tissue and progressively coalesce to form a cavity. Over time, the surrounding fibroblasts deposit collagen, giving rise to a structured wall and a narrow stalk that maintains communication with the joint space.

In both scenarios, focal myxoid degeneration within the connective tissue, coupled with sustained fibroblast activation and progressive accumulation of hyaluronic acid, forms the essential histological substrate that supports cyst initiation and long-term persistence [10]. Moreover, specific subtypes, such as digital mucous cysts, which are often associated with osteoarthritic changes of the distal interphalangeal joint, suggest that chronic degenerative alterations in cartilage and synovium may modify local matrix metabolism, promote mucin production, and thereby increase the risk of cyst formation and recurrence [11].

2.4 Mechanical Stress and Repetitive Loads

Chronic mechanical stress and repetitive joint loading are considered significant contributors to the formation and recurrence of ganglion cysts. Prolonged abnormal joint movement can create microtears or weak points in the joint capsule or tendon sheath, allowing synovial fluid to leak out and accumulate in the surrounding tissue. This process is particularly relevant in individuals who engage in high-impact activities or repetitive motion, which place continuous strain on the joint structures. The resultant fluid buildup can initiate the formation of a cyst, with a well-defined wall and stalk that maintains communication with the joint space. Furthermore, mechanical stress may amplify cyst formation by enhancing the production of mucinous substances. As repetitive loads continue, they could stimulate fibroblast activity and exacerbate extracellular matrix degeneration, further facilitating the accumulation of hyaluronic acid and the development of cystic structures. This biomechanical interaction not only promotes cyst formation but also plays a key role in maintaining its persistence and increasing the risk of recurrence, especially in areas subjected to continuous stress, such as the wrist or knee.

2.5 Recurrence Rates and Risk Factors

Reported recurrence rates show considerable variation across studies, largely due to differences in treatment approaches, duration of follow-up, and the extent to which the cyst pedicle or its communication with the joint cavity was managed during the procedure. Systematic reviews

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and multiple retrospective studies have indicated that simple aspiration carries a recurrence rate exceeding 50%. In contrast, cases involving complete surgical excision and closure of the joint communication, specifically those that include pedicle removal and repair or sealing of the joint capsule, show markedly reduced recurrence rate. But the reported rates still vary depending on technique and follow-up period, 1% to 20% for open excision and 9% to 17% for arthroscopic excision [12-14].

Multiple factors appear to influence the likelihood of recurrence, including the surgeon's level of experience, the specific operative approach, such as whether the pedicle was completely removed or the communicating tract repaired, and patient characteristics like sex, occupational load, and anatomical site of the cyst [13]. A more recent retrospective cohort analysis identified surgeon experience as one of the most significant determinants of recurrence: as operative skills improved and case volume increased, recurrence rates declined significantly. Additionally, some cohorts reported higher recurrence rates in male patients, possibly related to occupational mechanical load or anatomical differences. These findings suggest that, beyond the intrinsic characteristics of the lesion, modifiable factors such as surgical technique and intraoperative management of anatomical structures are key determinants in preventing recurrence [14].

3. Management and Recurrence Prevention

3.1 Natural Resolution and Observation

Ganglion cysts exhibit a certain degree of self-limiting behavior. According to the literature, the spontaneous resolution rate of ganglion cysts ranges from 50% to 60% [14]. Such natural regression typically occurs in individuals with smaller cysts, thin cyst walls, or limited communication with the joint cavity, possibly related to fluctuations in intracystic pressure and enhanced local resorptive capacity. However, a considerable proportion of patients experience recurrent enlargement or persistent cysts after temporary remission. Since the underlying anatomical and biological mechanisms responsible for cyst formation remain unaddressed, observation alone rarely eradicates the lesion. Although the spontaneous resolution rate is relatively high, recurrence can still occur, and this conservative approach is suitable only for patients with mild symptoms, small cyst size, or no significant functional impairment.

3.2 Immobilization-Based Approaches

Another traditional treatment approach, splint immobilization, is theoretically aimed at limiting joint motion, reducing intracystic pressure, and decreasing the influx of synovial fluid, thereby suppressing cyst expansion. In principle, prolonged immobilization may alleviate local mechanical stress; however, clinical outcomes have been limited. A follow-up study reported that after nine months of immobilization, most cases experienced recurrence once the splint was removed, suggesting that external fixation provides insufficient control over the cyst's fluid source. The lowest recurrence rates were observed in cases where postoperative management included firm bandaging or plaster splints to reduce tendon-sheath tension, which promoted incision healing and minimized fluid leakage [15]. Overall, evidence supporting splint immobilization as a preventive measure against recurrence remains weak. It is therefore considered more appropriate as a postoperative adjunct or transitional option during conservative treatment rather than a definitive therapy.

3.3 Aspiration and Pharmacologic Injection

Aspiration therapy is a widely used minimally invasive treatment for ganglion cysts, favored for its simplicity, minimal trauma, and low cost. The most common adjunctive medications are corticosteroids and hyaluronidase. Their mechanisms of action primarily involve reducing cyst fluid production and inducing fibrosis of the cyst wall. Steroid injection alone has been reported to provide initial symptom relief in approximately 87% of cases, although it may cause drug-related adverse effects such as subcutaneous fat atrophy and skin hypopigmentation. The combined use of corticosteroids and hyaluronidase can enhance cyst fluid degradation, temporarily delay recurrence, and improve the overall recovery rate to up to 95%, which is higher than that achieved with steroid monotherapy. However, this approach generally fails to completely obliterate the cyst pedicle or its communication channel, leading to limitations in long-term recurrence control. Some studies have begun exploring the feasibility of injecting sclerosing agents or biological adhesives into the cyst cavity to seal the channel, but randomized controlled trials are still lacking to validate their safety and efficacy. Preliminary research into the use of sclerosing agents and biological adhesives has shown promising results, with some studies reporting a reduction in cyst size and a lower recurrence rate compared to traditional aspiration alone. However, these results are based on small sample sizes, and further rigorous trials are needed to confirm their long-term effectiveness and safety.

3.4 Open Excision under Direct Visualization

Open excision remains the mainstay treatment for effectively reducing recurrence of ganglion cysts. The key advantage of open surgery lies in the direct visualization it provides, allowing the surgeon to fully expose the cyst and its pedicle, and to clearly excise the communicating tract between the cyst and the joint or tendon sheath. This approach markedly decreases the risk of recurrence. According to a study by Jonathan Lans et al., the pedicle is most commonly located on the dorsoradial aspect of the radiocarpal joint. Complete excision of the pedicle, combined with repair of the joint capsule opening, can effectively eliminate the source of cystic fluid and minimize recurrence. The reoperation rate after open excision was reported to be only 3.3%, all occurring within three years postoperatively [16]. Patient-reported recurrence was 13%, though only about one-fifth of those patients opted for repeat surgery. However, the drawbacks of open excision include potential postoperative scarring, joint stiffness, and risks of neurovascular injury, particularly during volar wrist procedures where critical structures are closely situated. Therefore, while striving for complete excision, surgeons must balance recurrence control with preservation of wrist function to achieve optimal clinical outcomes.

3.5 Arthroscopic Resection and Functional Outcomes

A large clinical series involving more than 1,600 cases reported that arthroscopic excision achieved a higher patient satisfaction rate of 89.2% and a lower recurrence rate of 9.4% compared with open surgery. In fact, recurrence rates following arthroscopic excision were found to be comparable to or slightly better than those of open surgery. Moreover, postoperative complication rates were relatively low, reported at 7.5% [17]. These findings suggest that arthroscopic excision achieves a favorable balance between recurrence control and functional recovery. However, the success of arthroscopic surgery is highly dependent on the surgeon's skill level and familiarity with wrist arthroscopic anatomy. Overall, whether the cyst pedicle is adequately addressed intraoperatively remains the most critical determinant of recurrence. Multiple retrospective studies have shown that when only the cyst body is excised without managing the pedicle or communicating tract, recurrence rates rise significantly. Conversely, when the pedicle is completely excised and the joint capsule opening is repaired, recurrence rates can be reduced to below 10%.

4. Novel Diagnostic and Therapeutic Approaches

4.1 Imaging Evaluation

High-resolution ultrasound and magnetic resonance imaging (MRI) are playing increasingly important roles in the diagnosis and preoperative planning of ganglion cysts. Ultrasound imaging can clearly delineate the cyst's fluid-filled characteristics, internal echogenic pattern, and spatial relationships with adjacent tendons, nerves, and blood vessels. It also allows dynamic visualization of the cyst pedicle's course.

MRI, owing to its superior contrast resolution, allows precise visualization of the cyst's origin and its connection to the joint cavity, which is particularly useful for volar wrist or deep-seated lesions. In comparative studies, MRI identified joint communication in 62% of cases, markedly higher than the 16% detection rate achieved with ultrasound [18]. Preoperative identification of the cyst pedicle through imaging markedly increases the likelihood of complete intraoperative excision, thereby reducing recurrence risk. MRI is especially suitable for complex or atypical cases, aiding in accurate localization and in determining whether to pursue an open or arthroscopic surgical approach.

4.2 Platelet-Rich Plasma Injection

In recent years, PRP has been explored as a prospective pilot therapy for the treatment of dorsal wrist ganglion cysts. PRP is rich in a variety of growth factors and cytokines, including platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β), and vascular endothelial growth factor (VEGF), which can modulate local inflammatory responses, promote tissue regeneration, and induce fibrosis. The proposed therapeutic mechanism involves the activation of PRP upon exposure to the cyst's collagenous wall after injection. This activation leads to the formation of an adhesive platelet clot within the cyst cavity, effectively obliterating the space and preventing recurrence [19]. The basic procedure for PRP injection involves drawing blood from the patient, typically 10-20 mL, which is then processed using a centrifuge to concentrate the platelets. The platelet-rich plasma is subsequently injected directly into the cyst cavity under ultrasound or fluoroscopic guidance to ensure accurate delivery. The procedure is minimally invasive, performed in an outpatient setting, and typically requires local anesthesia for patient comfort. Multiple sessions may be needed depending on the response, with a typical interval of 2-4 weeks between treatments. Although current studies are limited by

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small sample sizes, emerging evidence indicates that PRP therapy for dorsal wrist ganglia is safe, provides long-term pain relief, and demonstrates an extremely low recurrence rate [20].

4.3 Acupuncture and Needle-Based Therapies

In the treatment of ganglion cysts, needle-based interventions work primarily through mechanical stimulation and localized microtrauma, which induce the release of inflammatory mediators and activate tissue repair responses. In traditional Chinese medicine, acupuncture therapy has also been shown to effectively treat ganglion cysts. Following puncture of the cyst wall, local tissue exudation increases the activity of macrophages and fibroblasts, thereby promoting cyst fluid absorption and cyst wall fibrosis. Needle stimulation may additionally influence local nerve endings and microcirculation, helping to relieve pain, enhance metabolism, and facilitate reabsorption of cystic fluid. Insertion of an acupuncture needle through the cyst, traversing from one side of the cyst wall to the other, has been shown to stimulate local tissue activity, promote the dispersion of inflammatory mediators, and facilitate the absorption of gelatinous cystic fluid. In one reported case, the cyst size decreased from 1.8 cm to 1.72 cm after the first session, and to 1.55 cm the next day. The patient underwent treatment every other day, for a total of six sessions over three weeks, after which the cyst completely resolved. At six-month follow-up, there was no recurrence or related complication [21].

Although acupuncture appears to be a feasible and well-tolerated therapy, further experimental validation is required. The therapeutic effect is likely related to needle-induced local stress responses and immune modulation. Additionally, acupuncture has practical advantages such as simplicity, low cost, and high patient compliance. However, current evidence is mostly derived from case reports or small case series, lacking randomized controlled trials and blinded study designs. The optimal needle depth, angle, frequency, and cyst type influencing treatment outcomes remain unclear. Future studies should incorporate image-guided or ultrasound-assisted localization to achieve precise and reproducible puncture, and combine this with molecular-level investigations to elucidate the biological mechanisms underlying needle-induced fibrosis and cyst fluid absorption.

5. Conclusion

Tendon sheath ganglion cysts remain one of the most frequent benign lesions in hand surgery, yet their management is complicated by a substantial risk of postoperative recurrence rooted in anatomical and biomechanical persistence. The recurrence primarily arises from incomplete stalk excision, persistent one-way fluid communication with the joint cavity, and matrix-level degeneration within the cyst wall. Evidence from surgical series consistently shows that meticulous removal of the pedicle with capsule repair achieves the most durable outcomes, while advances in high-resolution imaging now enable more precise preoperative mapping of cyst–joint relationships, improving operative planning and reducing residual lesions.

Minimally invasive approaches such as platelet-rich plasma injection and acupuncture-guided decompression have introduced biologically driven alternatives that may reduce surgical morbidity. Nevertheless, these modalities remain constrained by limited sample sizes, short follow-up, and heterogeneous techniques, leaving their long-term value uncertain. Addressing this gap requires coordinated clinical trials supported by standardized imaging criteria and recurrence definitions. Future progress depends on linking microstructural pathology with intervention design, integrating imaging-based risk stratification, bioengineered sealing materials, and regenerative repair, to transform cyst management from empirical excision to mechanism-guided precision therapy that restores both tissue integrity and joint dynamics.

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