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Complications of Regional Anesthesia: A Comprehensive Review of Neurological Injury, Hematoma, and Infection

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Abstract

Background. Regional anesthesia is increasingly used due to its advantages over general anesthesia; however, its potential complications require careful evaluation.

Aim. This review aimed to synthesize current evidence on the incidence, risk factors, and prevention of neurological injury, hematoma, and infection associated with regional anesthesia.

Material and methods. Relevant peer-reviewed literature—including systematic reviews, retrospective cohorts, and randomized trials—was analyzed to provide a comprehensive overview.

Results. Neurological complications, though uncommon, may persist in a subset of patients and are linked to factors such as high-pressure intrafascicular injection and inadequate needle guidance. Hematomas remain rare but are more likely in patients on anticoagulants and can result in permanent deficits if diagnosis and decompression are delayed. Infections, particularly with prolonged catheter use, present a serious risk, with higher rates in peripheral nerve blocks and pediatric populations.

Conclusions. Preventive strategies include ultrasound guidance, triple safety protocols, careful antithrombotic management, and strict aseptic techniques. Recent evidence supports the efficacy of real-time pressure monitoring and prophylactic antibiotic use in reducing adverse outcomes. This review underscores the importance of patient-specific risk assessment and adherence to evolving safety protocols in minimizing complications from regional anesthesia.

Keywords: aneshesia, pediatric anesthesia, spinal anesthesia, Nerve block, complications, local anesthesia, difficult anesthesia

1. Introduction

The utilization of regional anesthesia (RA) has evolved into a fundamental component of contemporary perioperative care, attributable to its numerous benefits, including the capacity to curtail opioid utilization, enhance pain management, and mitigate adverse effects[1, 2]. Its applications encompass a wide range of surgical specialties, including orthopedic, obstetric, and general surgery, employing both neuraxial and peripheral approaches. While RA is widely regarded as safe, complications—though infrequent—can be calamitous, including permanent neurological deficits, spinal hematoma, and serious infections[3-5]. The incidence of these complications is low but not negligible. Recent studies have emphasized an increase in medico-legal claims related to RA complications, particularly in cases involving nerve injury or failure to recognize evolving hematomas [4]. While there is a broad consensus on the safety of RA

when performed under appropriate conditions, there is also divergence in the reported incidence of adverse outcomes between peripheral and neuraxial techniques and between patient subgroups (e.g., anticoagulated, elderly, or immunocompromised patients)[6, 7]. It is important to note that pediatric populations, which have historically been considered low-risk, have come to the forefront as a group that necessitates distinct considerations. This is due to their unique physiology and the evolving data on rare but serious complications. Given the pervasive utilization of RA and its expanding role in enhanced recovery pathways, a comprehensive understanding of its risks is paramount The present study differentiates between neuraxial and peripheral techniques and encompasses subjects that have received minimal discourse, including children. This review aims to synthesize recent findings regarding three major complications of regional anesthesia: neurological injury, hematoma, and infection. By identifying risk factors and prevention strategies, this review aims to highlight current gaps and opportunities to improve safety in regional anesthetic practice.

2. Materials and Methods

This narrative review examined the current literature on complications associated with regional anesthesia, specifically neurological injury, hematoma, and infection. A comprehensive search strategy was employed to identify relevant studies, encompassing major biomedical databases such as PubMed and Embase. These studies were selected based on a rigorous set of criteria, including relevance to the subject, methodological rigor, and clinical impact. The inclusion criteria encompassed peer-reviewed articles in English, encompassing randomized controlled trials, retrospective cohort studies, systematic reviews, meta-analyses, and registry analyses. The primary search focused on identifying incidence rates, risk factors, clinical outcomes, and preventive measures related to central neuraxial blocks and peripheral nerve blocks. A comprehensive search strategy was employed, incorporating keywords such as "regional anesthesia complications," "neurological injury," "spinal hematoma," "epidural abscess," and "infection after nerve block." Additional terms included “pediatric regional anesthesia,” “local anesthetic systemic toxicity,” and “catheter-related infection” to capture studies in underrepresented populations. The exclusion of studies was determined by the absence of adequate detail or methodological clarity. The data were extracted manually from each selected study and then synthesized descriptively to highlight common findings and clinical implications. Numerical data, including incidence rates and odds ratios, were tabulated or presented narratively where appropriate. Figure 1 was developed to illustrate key procedural and patient-related risk factors identified across the included studies. As this study did not involve original clinical trials, experimental data, or animal/human subjects, ethical approval was not required. All data and materials referenced are available to the public through recognized academic publishers or institutional repositories. It is imperative to note that no proprietary data or code was generated or analyzed as part of this review.

3. Results

3.1. Neuraxial Techinques

3.1.1 Neurological Injury

Neurological injury remains a rare but significant complication of regional anesthesia (RA), with the majority of cases resulting in transient sensory symptoms such as numbness, tingling, or paresthesia. Neuraxial techniques carry a risk of permanent injury ranging from 0 to 4.2 per 10,000 spinal anesthetics and up to 7.6 per 10,000 epidurals[8]. According to Zin [9], additional risk factors for neurological injury during neuraxial anesthesia include coagulopathy, anatomical abnormalities (e.g., scoliosis or spinal stenosis), and improper patient positioning

during needle insertion. A large retrospective cohort study found that among over 10,000 patients, neuraxial techniques were associated with a higher rate of persistent sensory or motor deficits at discharge compared to peripheral nerve blocks, with notable complications including epidural abscess and arachnoiditis[4]. As indicated by Puthenveettil et al., foot drop and other delayed neurological symptoms have been documented. These symptoms are potentially linked to direct needle trauma or hematoma formation in high-risk cases [10]. The timely identification of neurological symptoms and the implementation of a structured follow-up protocol are of paramount importance. The guidelines underscore that the presence of any new-onset motor deficit, urinary retention, or severe radicular pain following neuraxial anesthesia should prompt immediate imaging (typically an MRI) to rule out compressive etiologies such as hematoma or abscess [9-11]. A tertiary hospital study demonstrated that patients who received timely neurology consultation and imaging exhibited significantly superior functional recovery at discharge in comparison to those with delayed workup[4]. The early integration of physiotherapy and rehabilitation services has been demonstrated to be associated with enhanced outcomes in cases of partial motor recovery [12].

3.1.2. Hematoma

Spinal and epidural hematomas are rare but potentially devastating complications of regional anesthesia, with the risk of permanent neurological injury if not diagnosed and managed promptly. The estimated incidence of spinal hematomas is approximately 1 in 150,000 cases, while epidural hematomas have an estimated incidence of 1 in 220,000 cases in low-risk patients. However, this risk increases significantly in patients receiving anticoagulation or antiplatelet therapy [13-15]. A recent systematic review found that patients receiving antithrombotic medications had twice the risk of persistent neurological deficits if hematoma occurred, and non-adherence to ASRA guidelines increased the risk more than threefold [14]. Risk factors for developing hematomas include the use of anticoagulant medications, such as low-molecular weight heparin or aspirin, advanced age, female sex, traumatic or repeated needle insertion, and spinal pathology, including stenosis or vascular abnormalities[13-17]. It is noteworthy that hematomas can also occur in patients without obvious risk factors, underscoring the need for routine vigilance [18]. A study conducted by Kirkham revealed that as many as 68% of SEH cases exhibited coagulation impairment (predominantly from LMWH), while 25% involved challenging needle placement[17]. Preventive strategies emphasize strict adherence to antithrombotic management guidelines, individualized risk-benefit assessments, and early postoperative neurological monitoring[14, 15]. A rapid diagnosis using MRI and surgical decompression within 8 hours has been shown to yield the most favorable outcomes [19, 20]. One investigation revealed that, within a sample of 24 patients, those who underwent decompression within a shorter timeframe exhibited enhanced outcomes [21]. A comprehensive review of 940 spinal hematoma cases reveals that early recognition of symptoms and preexisting neurological status are more predictive of outcome than time to surgery alone [15]. Despite its rarity, spinal hematoma is a potentially life-altering complication that necessitates meticulous prevention, expeditious detection, and prompt intervention.

3.1.3. Infections

Although rare, infectious complications such as epidural abscess and meningitis represent some of the most serious risks associated with regional anesthesia. The overall incidence of infections following central neuraxial blocks is approximately 9 per 100,000, with central nervous system infections at 2 per 100,000 procedures, and as low as 1 per 100,000 for spinal anesthesia specifically [5]. Pediatric data align with these findings, reporting epidural abscess rates of 0.76 per 10,000 and cutaneous infections at 0.5% [22]. Risk factors for infection include prolonged

catheter duration, immunosuppression, systemic infections, and breaches in aseptic technique [8]. In a large-scale study encompassing 44,555 patients, Bomberg et al. (2018) observed a decline in infection-free catheter utilization, from 99% on day 4 to 95% on day 7, and to 73% by day 15[23]. These findings underscore the heightened infection risk associated with catheter retention for more than 4–5 days [23]. Domingues et al. further reported that 16.3% of epidural catheters were colonized by bacteria, most commonly Staphylococcus epidermidis, and that multiple puncture attempts increased the risk of colonization significantly (adjusted odds ratio: 4.52) [24]. Staphylococcus aureus remains the most frequent pathogen in epidural abscesses, while meningitis occurs more commonly after spinal than epidural anesthesia, according to a large case review of 234 meningitis cases[25]. It is noteworthy that even in low-risk populations, such as obstetric patients, vigilance is warranted as central nervous system infections, though rare, can occur [5]. Preventive strategies encompass the implementation of rigorous aseptic techniques, minimizing catheter duration, expeditious recognition of infection symptoms, and the administration of appropriate antibiotic prophylaxis [26]. Ecoffey et al. recommend the utilization of tunneled catheters for epidural access that extends beyond three days, the implementation of chlorhexidine skin preparation, and the assurance of routine site evaluation, particularly within pediatric contexts[26]. A substantial registry study demonstrated that a solitary prophylactic antibiotic dose diminished the risk of epidural catheter infection by nearly 40% [23]. The significance of these findings lies in their ability to underscore the paramount importance of infection control measures, even in cases where the procedure in question is considered to be routine.

3.2 Peripheral Techniques

3.2.1 Neurological Injury

The incidence of persistent neurological symptoms following peripheral nerve blocks is approximately 0.4 per 1,000 procedures, while temporary symptoms may occur in up to 3% of cases [27, 28]. Common persistent symptoms include sensory disturbances, residual pain, and mild motor weakness. A 2023 study reported that 17.4% of patients experienced neurological symptoms (numbness, weakness, or tingling) two weeks after interscalene block, and 12% of those continued to have symptoms at 6 months[29]. A one-year follow-up study found that 23% of patients reported numbness or paresthesia, 27% reported residual pain, and 20% experienced motor weakness, although most symptoms were mild in 89% of cases[30]. Key risk factors for neurologic injury include needle trauma, high injection pressure, intrafascicular injection, ischemia (due to vasoconstrictors or hypotension), and pre-existing neuropathy or obesity[8, 31]. Experimental studies have demonstrated that high-pressure intrafascicular injections are particularly deleterious. A cadaveric analysis of 664 nerve cross-sections revealed actual intrafascicular spread in a mere 6 cases, thereby suggesting that, while ultrasound guidance enhances safety, fascicle penetration continues to carry a significant level of risk [32]. The utilization of a triple guidance system, encompassing ultrasound, a nerve stimulator, and pressure sensing, led to a substantial reduction in the occurrence of unintentional intraneural injections[33]. Real-time pressure sensing at the needle tip detected high-resistance (unsafe) injections, helping operators avoid intrafascicular spread[33]. To mitigate these risks, a multifaceted approach is recommended, encompassing the use of ultrasound guidance, the employment of low-pressure injection techniques, the avoidance of deep sedation, and meticulous preoperative neurological assessments[31, 33, 34]. The ongoing development of real-time pressure monitoring and ultrasound training holds promise in further enhancing safety[34, 35]. While most neurological symptoms are transient, the potential for persistent deficits underscores the necessity for vigilance and adherence to established protocols.

3.2.2 Hematoma

While peripheral nerve blocks are considered to be a relatively safe procedure, recent findings have emerged that highlight the potential for hematomas and neurological complications, albeit infrequent, to have clinical significance and the potential to result in long-term morbidity. These risks are particularly elevated in patients receiving antithrombotic therapy, with bleeding rates estimated at approximately 0.67%, especially in deep or non-compressible block sites [36, 37]. A substantial study encompassing 6,012 patients revealed that 13.2% encountered neurological complications subsequent to PNBs, with 2.9% experiencing these complications over an extended duration, particularly following popliteal blocks [38]. Pediatric data also show notable risks, with up to 10% experiencing chronic motor deficits or pain [39]. The identification of risk factors, as outlined in the research by Lauf et al., encompasses a range of demographic and behavioral characteristics, including age between 40 and 65 years, current smoking, low BMI, and a history of repeated needle insertion [40]. While the available prospective registry data supports the overall safety of PNBs, consistent with high patient satisfaction, these findings underscore the need for careful patient selection, ultrasound guidance, and strict adherence to antithrombotic management protocols [41]

3.2.3 Infections

Recent studies have demonstrated that, while peripheral nerve block (PNB) catheters carry a measurable risk of infection, the overall incidence remains low when the proper technique and duration limits are employed. Risk factors for infection include prolonged catheter duration, immunosuppression, systemic infections, and breaches in aseptic technique [8]. A comprehensive retrospective analysis of 484 catheters in burn patients revealed an infection rate of 1.2% per catheter and 2.1% per patient, which is analogous to infection rates observed in other surgical populations [42]. In a similar vein, Bomberg et al. observed a progressive decline in infection-free catheter use after day 4, accompanied by a notable escalation in risk beyond 7–10 days[23, 43]. These findings underscore the significance of prompt removal and the administration of antibiotic prophylaxis in cases of prolonged use. These findings align with the prevailing consensus that catheter duration beyond 4–5 days, particularly in the absence of prophylaxis, constitutes a significant modifiable risk factor [23, 43]. Coagulase-negative staphylococci persist as the most prevalent isolated organisms from colonized peripheral nerve catheters, mirroring a microbiological pattern analogous to that observed in neuraxial catheter infections[42]. This finding underscores the significance of adhering to stringent aseptic technique during catheter insertion and handling to avert colonization by skin flora, particularly in the context of prolonged catheter use [42].

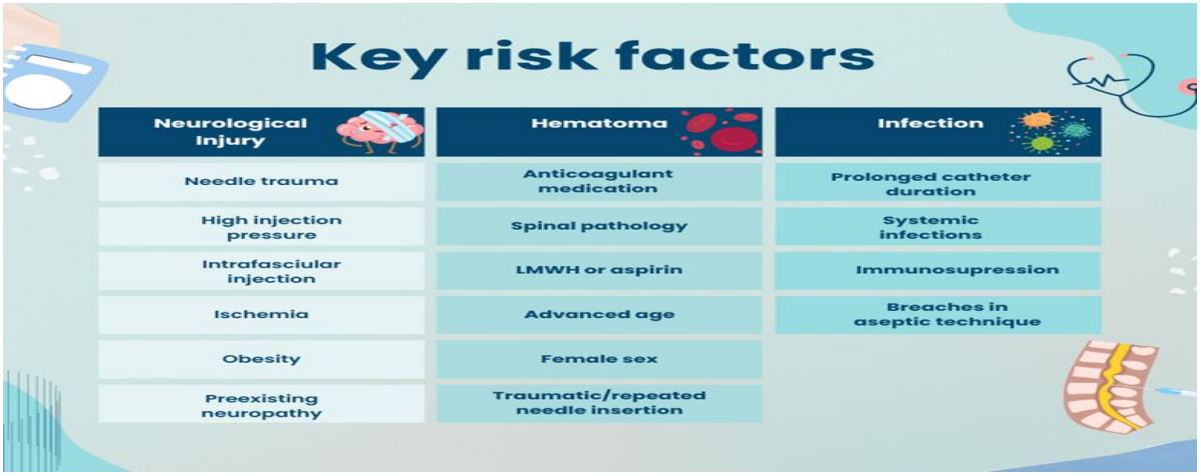

Figure 1. Key risk factors associated with complications of regional anesthesia.

The following infographic summarizes the primary patient-related and procedural risk factors contributing to neurological injury, hematoma, and infection. This visual representation serves to underscore the multifactorial nature of these complications and underscores the necessity for individualized risk assessment and targeted preventive strategies.

Table 1. Offers a concise synopsis of the pivotal studies cited in this review, encompassing their methodological framework, investigative focus, and salient conclusions.

Author	Study Design	Topic	Key Findings
Brull et al.	Systematic Review	Neurological Injury	0.4/1,000 incidence of persistent symptoms; most are transient
Radkowski et al.	Narrative Review	Neurological Injury	Updated clinical guidelines; risk factors and outcomes summarized
Reina et al.	Cadaveric Study	Neurological Injury	Intrafascicular injection risk even with ultrasound
Schieber et al.	Systematic Review	Hematoma	Antithrombotics increase severity and risk
Vu et al.	Case Report	Hematoma	Spinal hematoma linked to long-term aspirin
Baeesa et al.	Observational Study	Hematoma	Early MRI and decompression linked to better outcomes
Selvamani et al.	Narrative Review	Infection	Infectious complications rare but serious; risk factors reviewed
Bomberg et al.	Registry Study	Infection	Infection-free rates decline after day 4; antibiotic prophylaxis beneficial
Domingues et al.	Hospital-Based Study	Infection	16.3% catheter colonization; Staph. epidermidis most common
Coudray et al.	RCT	Prevention Strategies	Triple guidance reduces intraneural injection risk
Ecoffey et al.	Practice Advisory	Pediatric Infection Control	Recommends tunneling, chlorhexidine, site checks
Frost et al.	Secondary Analysis of RCTs	Neurological Injury	17.4% had symptoms after 2 weeks; 12% had persistent symptoms at 6 months
Siddiqui et al.	Follow-Up Study	Neurological Injury	Long-term symptoms: numbness (23%), pain (27%), motor weakness (20%)
Kirkham & Albrecht	Review	Hematoma	68% of SEH cases had coagulation issues; 25% had traumatic needle insertions
Walker et al.	Registry Analysis	Pediatric Infection Risk	Epidural abscess rate 0.76/10,000; cutaneous infection rate 0.5%
Zorrilla-Vaca et al.	Meta-Analysis	Infection - Meningitis	Meningitis more common after spinal than epidural anesthesia

3.3 Pediatric patients

The safety of regional anesthesia in pediatric populations is generally considered to be contingent upon the expertise of the practitioner. However, it is important to acknowledge that the procedure is not without risk. Neurologic complications, including transient or occasionally permanent nerve injury, persist as a concern. A comprehensive database review has substantiated that the incidence of such injuries in children is comparable to that observed in adults, suggesting an overall safety pattern but underscoring the necessity for vigilance [44]. Peripheral nerve blocks, which have seen increased utilization in orthopedic procedures, have been associated with prolonged sensory and motor deficits[45]. However, the extant data on

long-term outcomes remains limited[45]. According to the findings of Lam et al., 14.4% of patients exhibited transient postoperative neurological symptoms lasting less than ten days following peripheral nerve block[46]. Local anesthetic systemic toxicity is a rare but possible complication, especially with continuous infusions or higher dosages[47]. Ultrasound guidance has been demonstrated to reduce the risk of this complication [47]. A comprehensive literature review has revealed that over 50% of pediatric LAST cases occur in children under the age of three, often without early warning signs such as seizures, which may be masked by the effects of general anesthesia[48]. Clinical updates underscore the fact that, while the incidence of LAST is low (approximately 8/100,000 in children), infants are overrepresented in reported cases, especially in penile and caudal blocks[49]. Risk factors for complications include preexisting neurological disorders, coagulation abnormalities, younger age, and critically ill status [50, 51]. The guidelines underscore the significance of preventive measures, including the utilization of chlorhexidine for skin preparation, catheter tunneling for epidurals, and meticulous patient selection when on anticoagulants[52, 53].

4. Discussion

The findings of this review affirm that, while regional anesthesia is generally safe, it carries a measurable risk of complications that demand clinical attention and preventive strategies. Neurological injury, although uncommon, presents with a range of symptoms from transient paresthesia to persistent sensory and motor deficits. The incidence rates and long-term symptom persistence reported in recent studies challenge earlier assumptions of transient and benign outcomes. These results align with extant literature highlighting mechanical and ischemic mechanisms of nerve injury, and support the increasing adoption of triple guidance techniques—ultrasound, nerve stimulation, and injection pressure monitoring—as validated safety enhancements. This trend is also evident in pediatric populations, where prolonged neurological symptoms, albeit uncommon, have been reported, particularly following proximal peripheral blocks.

In the case of hematoma, our findings corroborate the notion that patients receiving anticoagulation therapy face the greatest risk, a finding that is consistent with prior advisories issued by the ASRA and the findings of clinical registries. The review further emphasizes that not only the timing of decompression but also the patient's preoperative neurological condition significantly influence recovery outcomes. This nuanced understanding has been increasingly reflected in recent surgical outcome data and supports the need for vigilant postoperative monitoring, even in cases that are guideline-compliant. In pediatric patients, particular consideration is imperative when assessing coagulation status and preexisting conditions, as even low-dose anticoagulants have been associated with rare but serious neuraxial bleeding events.

Although rare, the occurrence of infectious complications appears to be more prevalent than hematomas and remains largely preventable. The evidence that has been reviewed indicates that the risk of infection is increased by three factors: catheter dwell time, inadequate aseptic practices, and multiple puncture attempts. Recent studies in both pediatric and adult populations have highlighted the efficacy of a multifaceted approach, including tunneling, routine site checks, and the administration of a single prophylactic antibiotic dose, in significantly reducing colonization and infection rates. In the context of pediatric practice, the utilization of tunneled catheters and chlorhexidine-based antisepsis has been strongly recommended for epidural applications beyond three days. Moreover, daily site inspection has been identified as a critical component of infection prevention measures.

Taken together, these results underscore the significance of patient-specific risk assessment and strict adherence to best practices. From a broader perspective, the data reflect a shift in regional

anesthesia toward precision-guided, multimodal safety strategies. This encompasses the adaptation of techniques and guidelines for vulnerable groups, such as pediatric, elderly, or neurologically impaired patients. Future research should prioritize the validation of real-time monitoring technologies, the development of predictive tools for complication risk, and the long-term safety profiling of regional techniques in vulnerable populations, such as the elderly and immunocompromised individuals.

To synthesize the extant evidence-based recommendations, Figure 2 presents a visual outline of the four most validated prevention strategies for complications associated with regional anesthesia. These include the triple guidance protocol (ultrasound, nerve stimulation, and pressure monitoring) to reduce the risk of intraneural injections; rigorous aseptic technique to prevent infections; individualized antithrombotic management to minimize hematoma risk; and the use of prophylactic antibiotics, which has shown efficacy in lowering infection rates, especially in long-term catheterization. The consistent incorporation of these strategies across clinical settings is imperative for enhancing procedural safety and improving patient outcomes.

Figure 2. Prevention strategies for complications associated with regional anesthesia.

5. Conclusions

Regional anesthesia is widely regarded as safe and effective, but this review reveals that it carries significant risks. While neurological injuries are often transient, they can result in persistent deficits in a substantial subset of patients, particularly when high-pressure intrafascicular injection or needle trauma occurs [3, 27]. Hematomas are rare but can lead to severe outcomes if diagnosis or decompression is delayed, especially in patients receiving antithrombotic therapy [13, 14, 19]. Similarly, infections, particularly from prolonged catheter use or poor aseptic technique, can lead to abscesses and meningitis with serious neurological

consequences[5, 23, 24]. This review supports a growing consensus across all complication types that risk is multifactorial, dependent not only on patient-specific factors such as comorbidities and medications but also on procedural elements such as technique, sedation depth, and aseptic measures[31, 52]. Techniques such as ultrasound guidance, pressure-sensing needles, and triple guidance protocols have been shown to measurably reduce adverse outcomes[33, 35]. This safety-focused paradigm is equally applicable to pediatric patients, who face unique risk factors including immature physiology, increased sensitivity to local anesthetics, and difficulty in early symptom recognition.. Ultimately, preventing complications from regional anesthesia requires individualized risk assessment, adherence to updated clinical guidelines, and adoption of multimodal safety strategies. In the context of pediatric practice, the implementation of weight-based dosing has been identified as a critical component, in conjunction with the employment of tunneled catheters and meticulous site inspection protocols. These methodologies have garnered substantiation through the recent guidelines established by the joint efforts of the ASRA and ESRA. Future research should prioritize refining real-time monitoring technologies, developing predictive tools for high-risk patients, and analyzing the long-term outcomes of regional anesthesia in vulnerable populations. Particular attention should be given to children and patients with neurologic or coagulation disorders, where complication profiles may differ significantly from the general population.

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