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Swimming-Induced Pulmonary Edema in Open-Water Sports: Implications for Athlete Health and Event Medical Care — A Narrative Review

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Abstract

Background: Swimming-induced pulmonary edema (SIPE) is an uncommon but potentially serious complication of open-water swimming and triathlon. For event medical teams, the challenge extends beyond diagnosis to safe extraction, race-side assessment, respiratory support, and decisions about transfer or discharge.

Objective: To review the clinical, physiological, and event-medicine literature on SIPE and develop a practical framework for medical care at mass-participation open-water events. Methods: We searched PubMed/MEDLINE and supplemented the search with Google Scholar, Semantic Scholar, Crossref, publisher websites, and citation tracking. Because the review was intended to inform event medicine, studies conducted in mass-participation settings were given greatest weight, with military, diving, physiological, and other clinical literature used when directly relevant.

Results: Direct event evidence is concentrated in a small number of overlapping Vansbro cohorts. In symptomatic swimmers, pulse oximetry and auscultation performed well against LUS-confirmed pulmonary edema; at one low-altitude event, SpO_2 ≤95% or crackles gave 97% sensitivity and 86% specificity. These figures are specific to that setting. Lung ultrasound can add useful information, particularly because edema may be focal or anterior. CPAP and PEP have both been used on site with clinical improvement in observational data, but the available observational data do not establish comparative effectiveness. Crackles and B-lines may persist after symptoms and oxygenation improve. Severe, atypical, or non-resolving presentations require escalation.

Conclusions: The literature supports a coherent sequence of event care: preparation, recognition, extraction, assessment, supportive treatment, reassessment, and a decision between escalation and stable disposition, followed by handover and follow-up. The framework proposed here is intended as a practical aid for local adaptation, not as a validated clinical protocol.

Keywords: swimming-induced pulmonary edema; immersion pulmonary edema; open-water swimming; triathlon; event medicine; prehospital care; lung ultrasound; continuous positive airway pressure.

1. Introduction

Open-water swimming places athletes in a setting where exertion, immersion, environmental exposure, and limited access to immediate rescue occur simultaneously. Swimming-induced pulmonary edema (SIPE) usually develops during or shortly after surface swimming and has been described in military swimmers, recreational athletes, and triathletes [1-5]. Dyspnea out of proportion to effort, cough, chest tightness, hypoxemia, crackles, frothy sputum, and hemoptysis are typical features. Severity varies widely: some athletes improve quickly after

leaving the water, whereas others develop marked desaturation, altered consciousness, or respiratory failure requiring ambulance transfer and advanced support [6-9]. Cardiac abnormalities may accompany the pulmonary presentation. Case reports cannot resolve whether these findings are cause, consequence, or coincidence, but they make a concurrent cardiac process an important part of the differential diagnosis [10-13].

At a mass-participation race, SIPE becomes a systems problem as soon as symptoms arise. Someone must recognize that the swimmer is in difficulty, have the authority to stop further participation, extract the athlete safely, and move them into a pathway that allows assessment, oxygen or ventilatory support, observation, and transport if needed. Triathlon medical reports describe this chain across the water, swim exit, transition, mobile course teams, finish-area care, ambulance services, and receiving hospitals [14-16]. The staffing models in those reports are event-specific and should not be treated as universal standards. SIPE has also been proposed as one contributor to swim-related deaths, although retrospective and postmortem attribution remains uncertain [17-18].

The most informative estimate from a civilian mass-participation event comes from Vansbrosimningen in Sweden. Investigators classified 211 SIPE episodes among 47,573 started swimming distances, an incidence of 0.44% (95% CI 0.39–0.51) [19]. That number should be read as an event estimate rather than a general prevalence figure: it reflects the local environment, participant mix, case definition, surveillance system, and the use of started distances rather than unique individuals as the denominator. Military cohorts, self-reported surveys, and small case series answer different questions and are not directly comparable.

Recognition is not always straightforward. A swimmer may still be moving well enough to continue, may downplay symptoms, or may interpret a sudden fall in performance as poor pacing, anxiety, cold, or a technical problem. Interviews with affected swimmers describe unusual breathing sounds, abrupt fatigue, cognitive changes, and deliberate concealment of symptoms in addition to more familiar respiratory complaints [20]. These accounts are useful for prompting questions, but they are not diagnostic criteria. Reports from triathlon also show that symptoms beginning in the water may only be disclosed at transition or during the cycling leg; this is better understood as delayed recognition than as proven late-onset SIPE [21].

The recent event literature is particularly useful because it addresses decisions that actually arise at race side. In symptomatic swimmers, pulse oximetry and chest auscultation discriminated reasonably well between those with and without LUS-confirmed pulmonary

edema, while ultrasound showed that edema can be focal, anterior, or unilateral [6]. Treatment data are less definitive. A prospective cohort showed that CPAP and PEP could both be delivered on site and that oxygenation and symptoms improved during care, but there was no untreated comparison group and the study was not designed to establish equivalence between the two techniques [22-24].

Earlier reviews have largely been organized around epidemiology, mechanisms, diagnosis, recurrence, and prevention [25-28]; a recent scoping review also considered management and resource-limited care [29]. The question addressed here is different. Event clinicians work through a sequence of decisions rather than through isolated topics. We therefore organize the evidence in the order in which a suspected case is encountered: preparedness and recognition, extraction, assessment, treatment, reassessment, escalation or discharge, handover, follow-up, and review of the event response. The resulting pathway is deliberately pragmatic and is not presented as a formal guideline.

2. Review methods

We performed a narrative review centered on the practical management of SIPE at mass-participation open-water events. PubMed/MEDLINE was the primary database. Searches were supplemented with Google Scholar, Semantic Scholar, Crossref, publisher websites, and backward and forward citation tracking. The main search was completed on 23 July 2026, followed by an update for newly published records on 13 September 2026. Search terms covered swimming-induced and immersion pulmonary edema, open-water swimming, triathlon, recognition, diagnostic assessment, prehospital treatment, transport, follow-up, and event-medical organization. We included reports dealing directly with SIPE and, where they informed a specific clinical or operational question, relevant evidence from military swimming, diving, physiology, and event medicine. Event-based SIPE studies were treated as the most directly transferable evidence; findings from other settings were interpreted more cautiously. Duplicates and clearly unrelated records were excluded. Selection was based on relevance to the review question rather than on a prespecified systematic-review screening protocol, and we did not undertake formal risk-of-bias or GRADE assessment. Because designs, populations, definitions, and outcomes varied substantially, the literature was synthesized narratively rather than quantitatively. The final corpus comprised 57 retained evidence records. The study-selection process is summarized in Figure 1.

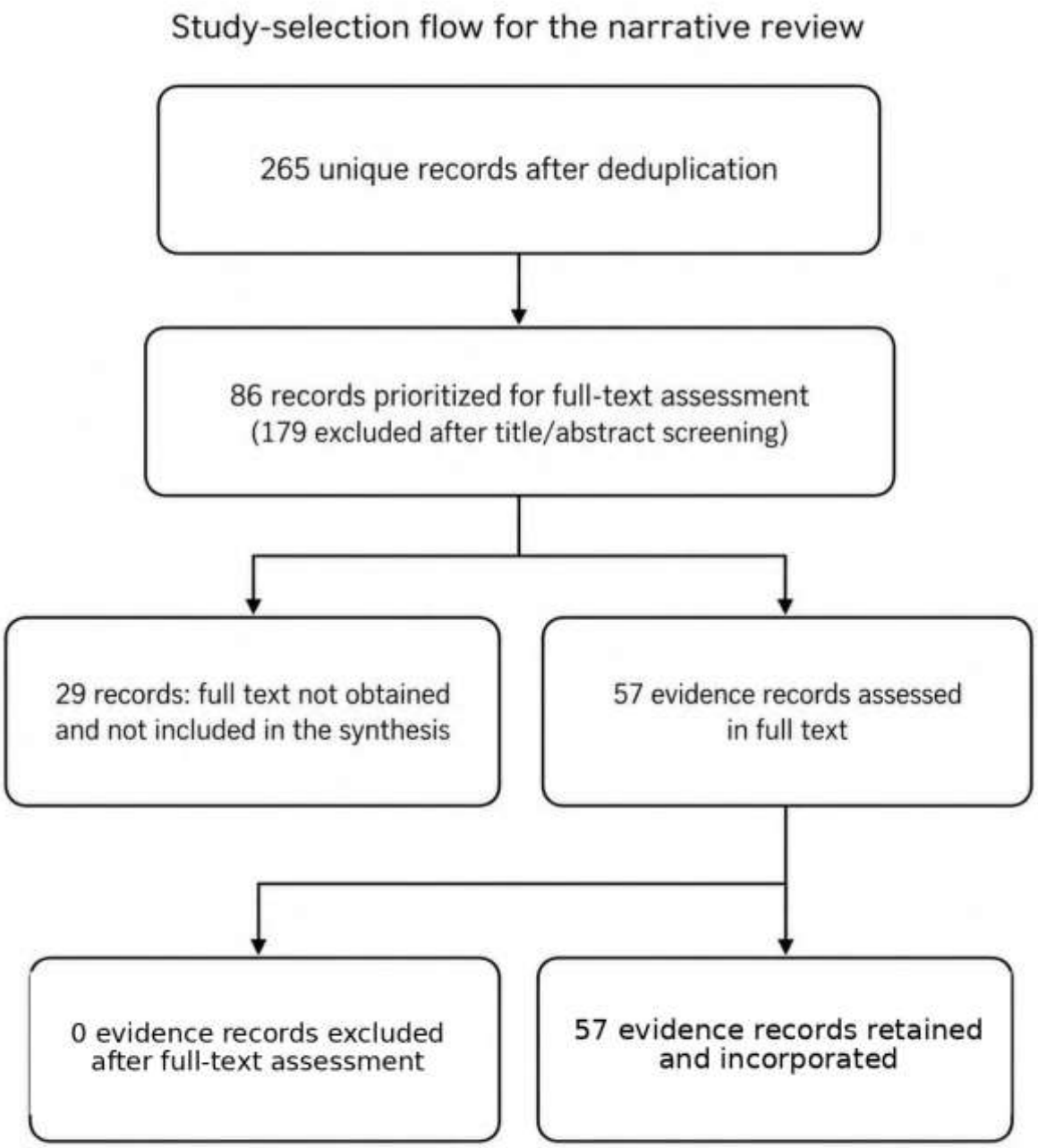

Figure 1. Study Identification and Selection Process.

3. Results and discussion

3.1 Event burden, preparedness, and recognition

Reported occurrence varies markedly across studies, largely because the populations, exposure patterns, case definitions, and denominators are different. In the largest prospective civilian event cohort, 211 SIPE episodes occurred during 47,573 started swimming distances, giving an event-specific incidence of 0.44% (95% CI 0.39–0.51) [19]. Rates were higher in women and rose with age. These associations are relevant to that event population but should not be interpreted as population-wide incidence estimates.

Risk-factor data are similarly context dependent. In the largest event-based case-control study, female sex, older age, hypertension, heart disease, asthma, and limited open-water exposure in the current season were independently associated with SIPE in one model. A second model placed greater weight on previous respiratory symptoms during open-water swimming and recent respiratory tract infection, while asthma was no longer statistically significant [30]. A separate study in Naval Special Warfare candidates found respiratory pathogens more often in SIPE cases than in controls, which supports a possible role for respiratory infection in that specific military population [31]. Earlier surveys and case clusters are more vulnerable to selection and ascertainment bias [32-33]. Repeatedly examined military trainees have also shown much higher cumulative event rates; in one field study, 29 episodes were diagnosed in 21 of 35 trainees over two months [34]. That exposure is too different from a single civilian race for the figures to be compared directly.

For organizers, fixed staffing ratios are less useful than knowing which functions must be available and how athletes move between them. A workable system needs a route from recognition and extraction to shore-side assessment, oxygen and warming, monitoring, communication, and transport, with the details shaped by course geometry and local resources [15-16]. Education can be equally practical: athletes and staff should recognize new or disproportionate breathlessness, persistent cough, chest symptoms, altered behavior, or an abrupt unexplained drop in performance [21,35]. Previous SIPE deserves attention, but neither recurrence risk nor prevention is well enough defined to support a standard screening strategy. Studies of sildenafil, neoprene compression, negative-pressure breathing, respiratory compliance, and immersion-induced mitral regurgitation remain small or mechanistic and are better viewed as hypothesis-generating [36-41].

A suspected case may first become apparent in the water, at the swim exit, in transition, or later in the race. This is why active questioning matters: some athletes minimize symptoms or actively conceal them [5,20]. Persistent dyspnea, cough, noisy breathing, an unexpected loss of pace, poor recovery after leaving the water, or confusion are reasonable triggers for a formal assessment [21,35]. Chest pain, syncope, persistent hypoxemia, hemodynamic instability, arrhythmia, or failure to improve shift the concern toward a more serious or concurrent diagnosis, including myocardial injury or Takotsubo cardiomyopathy [11-12].

3.2 Race-side assessment and differential diagnosis

Race-side assessment has two immediate aims: determine how sick the athlete is and identify findings that would change the differential diagnosis or disposition. A practical initial assessment includes mental status, respiratory rate and work of breathing, SpO_2 with a reliable waveform, heart rate, blood pressure, a focused chest examination, and brief questioning about chest pain, syncope, aspiration, and trauma. In a study of 160 symptomatic event admissions, LUS showed pulmonary edema in 102. Either SpO_2 $\leq$95% or crackles identified LUS-confirmed edema with 97% sensitivity and 86% specificity; requiring both findings increased specificity to 98% [6]. These numbers are useful as event data, not as universal diagnostic cutoffs.

The distribution of edema also matters for examination. Focal and anterior abnormalities were seen on ultrasound, so limiting auscultation to posterior fields risks missing relevant findings [6]. LUS can be helpful when equipment and trained operators are available, but B-lines are not specific for SIPE and can appear after strenuous exercise in asymptomatic athletes [6,42]. At race side, alternative diagnoses include aspiration or drowning-related lung injury, bronchospasm, infection, pneumothorax, pulmonary embolism, acute coronary syndrome, arrhythmia, hypothermia, exercise-associated hyponatremia, and heat illness [27-28,43-45]. Infrared tympanic temperature measurement is a poor screening test for hypothermia immediately after open-water swimming [46].

Cardiac findings need the same contextual approach. Mild transient ventricular abnormalities and troponin elevation have been reported with SIPE, while severe chest pain or a marked biomarker rise may point to a separate myocardial event [12]. Diving cohorts provide supporting but indirect evidence: transient myocardial dysfunction, troponin release, and occasionally subtle or rapidly resolving radiographic abnormalities have all been described [47-

50]. This supports hospital evaluation when the presentation is severe or atypical. It does not support routine biomarker testing at the race venue.

3.3 Management, reassessment, and escalation

The first treatment step is to end the exposure: stop swimming and remove the athlete from the water. Management then focuses on oxygenation, respiratory distress, and prevention of further cooling. Wet or restrictive equipment can be loosened or removed if it impairs breathing, examination, or warming. Evidence from a single physiological report is not enough to treat wetsuit modification as a preventive intervention [38]. Supplemental oxygen is appropriate when hypoxemia or substantial respiratory compromise is present, and the response should be followed over time rather than judged from a single saturation value.

The largest event-treatment series included 119 patients; 94 received CPAP, 24 PEP, and one was intubated. Median SpO_2 rose from 91% to 97%, symptoms improved, 108 patients were discharged from the event medical unit, and 11 were transferred [22]. These data show feasibility in an experienced service, not treatment efficacy. They also do not establish CPAP and PEP as interchangeable. The choice of modality, pressure, treatment duration, and observation or discharge threshold remains uncertain [22-24]. Of note, crackles and LUS abnormalities often outlasted the clinical improvement. Reassessment should therefore emphasize how the patient feels and breathes, whether oxygen is still required, hemodynamic stability, and whether symptoms recur as support is reduced [22]. Diuretics, nitrates, bronchodilators, and intravenous fluids have no established role as routine SIPE-specific treatment [27].

Transfer decisions are best made from the whole clinical picture rather than from a single threshold. Severe or worsening respiratory distress, persistent hypoxemia, recurrent deterioration, altered consciousness, hemodynamic instability, significant chest pain or syncope, suspected aspiration, and failure to improve all favor escalation. Event capability matters as well: limited monitoring, oxygen supply, airway support, or ability to reassess should lower the threshold for hospital transfer. The 9% transfer rate reported at Vansbro describes local practice and is not a benchmark [22]. A useful handover includes when symptoms began, the exposure history, possible aspiration, serial observations, treatments given and the response, any recurrence after support was reduced, and cardiac or neurological red flags. Receiving teams should also know that dramatic prehospital findings may partly resolve before arrival;

residual crackles, B-lines, imaging abnormalities, or biomarker changes still need clinical interpretation [22,49-50].

3.4 Disposition, follow-up, and return to swimming

Discharge from the event medical unit should be considered only after a sustained recovery rather than after normalization of a single measurement. In practical terms, respiratory distress should be close to resolved, room-air SpO_2 should remain stable at a locally appropriate level, symptoms should not recur after support is withdrawn, mental status and hemodynamics should be normal, and the athlete should mobilize safely without evidence of another diagnosis requiring hospital assessment. Residual crackles or B-lines alone are not a reason to transfer, but a normal oxygen saturation alone is not enough to discharge. There are no validated criteria for return to swimming after SIPE. From an event-safety perspective, same-day return to competition should generally be avoided after treatment for a clinically significant suspected episode.

Recovery is not always complete by the time an athlete leaves medical care. In the largest follow-up cohort, 132 of 165 participants were assessed at 10 days and 152 at about 30 months; 38% reported symptoms lasting longer than two days [51]. Of the 64 participants who later returned to open-water swimming, 18 (28%) described recurrent respiratory symptoms. Those later episodes were self-reported and were not consistently confirmed as SIPE, so the figure should not be read as a verified recurrence rate.

Evidence on recurrence comes from populations that differ too much to combine meaningfully. Hypertension was associated with recurrence in one diving cohort, and a small historical series reported frequent later development of hypertension, but neither finding establishes prediction or causation in civilian swimmers [52-53]. Severe, recurrent, objectively documented, or otherwise atypical episodes justify individualized cardiovascular and pulmonary assessment, particularly when chest pain, syncope, arrhythmia, an abnormal ECG, marked biomarker elevation, persistent symptoms, or structural heart disease is present [54-55]. Normal testing on land does not exclude an immersion-specific problem. No validated return-to-swimming protocol exists, and current evidence does not support routine sildenafil prophylaxis [36-37,56]. Written follow-up instructions are worth providing because adherence after event medical care is often incomplete [57].

3.5 Operational pathway and principal evidence

Figure 2 summarizes how these findings can be turned into an event workflow. The pathway starts before the race, with preparation, and then moves through recognition, extraction, assessment, supportive care, reassessment, and either escalation or stable disposition, followed by handover and follow-up. The event literature gives the best support to symptom-triggered assessment, pulse oximetry, auscultation, oxygen when needed, repeated clinical review, and escalation of severe or atypical cases. Other parts of the pathway are less settled. Diagnostic cutoffs, choice of positive-pressure device, duration of observation, discharge criteria, return-to-swimming decisions, and resource requirements still depend heavily on local context and need external validation.

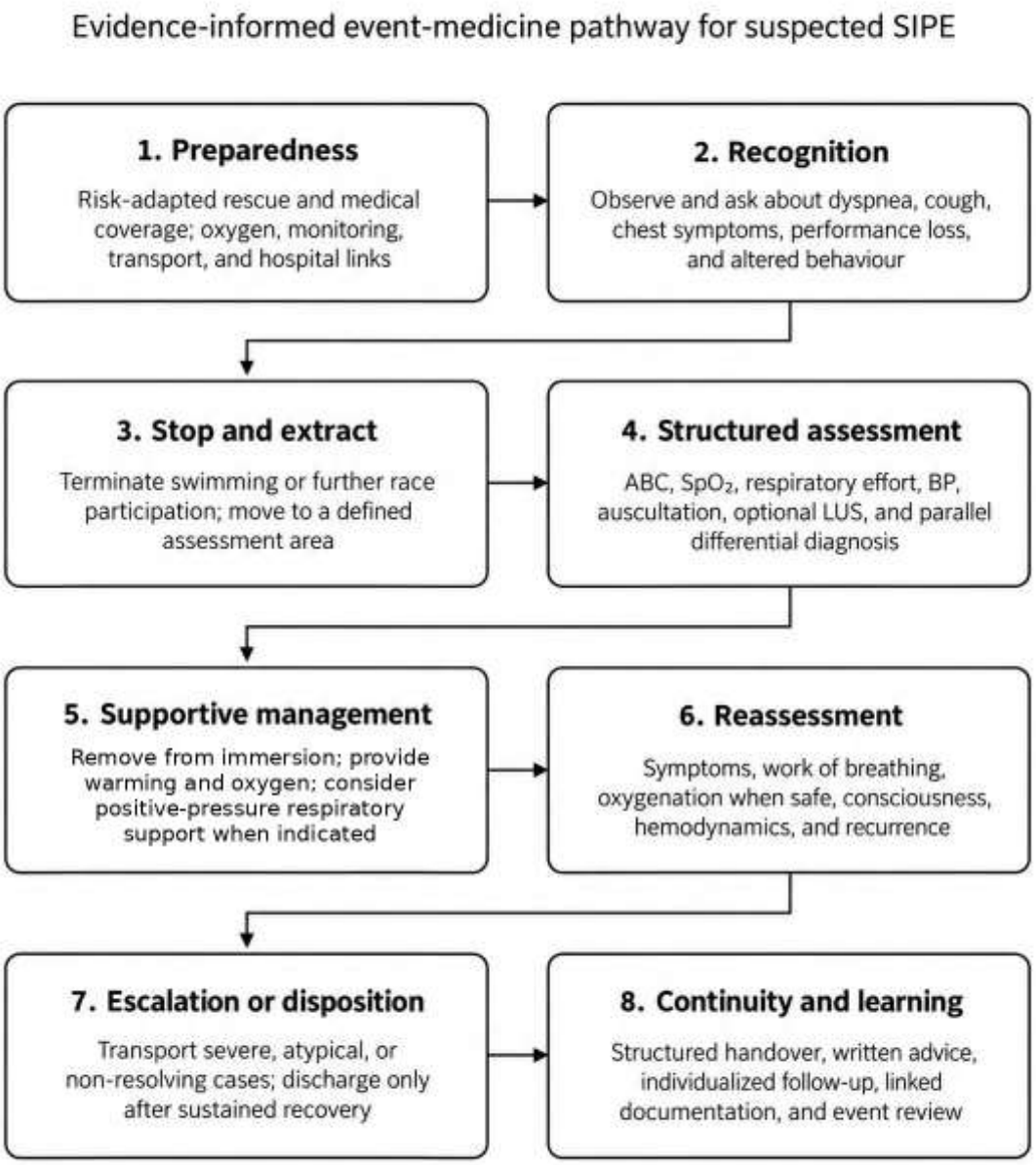

Figure 2. Evidence-informed event-medicine pathway for suspected SIPE. Implementation requires adaptation to local capabilities.

Abbreviations: ABC, airway, breathing, and circulation; BP, blood pressure; CPAP, continuous positive airway pressure; LUS, lung ultrasound; SIPE, swimming-induced pulmonary edema; SpO_2, peripheral oxygen saturation.

Table 1. Principal evidence informing the event-medicine framework

Study	Design / population	Operational contribution	Primary limitation
Hårdstedt et al., 2020 [6]	Diagnostic event study; 160 symptomatic admissions	SpO_2 and crackles identified LUS-confirmed pulmonary edema; focal, anterior, or unilateral patterns occurred	One low-altitude cold-water event; endpoint was pulmonary edema on LUS, not definitive etiology
Hårdstedt et al., 2021 [19]	Prospective event cohort; 47,573 started distances	Event-specific incidence 0.44%; higher incidence among women and older groups	Event-specific; ascertainment evolved; distances rather than unique persons
Seiler et al., 2022 [22]	Prospective observational treatment cohort; 119 patients	On-site CPAP/PEP feasible; oxygenation and symptoms improved; LUS/crackles persisted	No untreated control; comparative effectiveness of CPAP and PEP not established; local disposition practice
Kristiansson et al., 2023 [51]	Longitudinal event follow-up; 165 index cases	38% reported symptoms >2 days; 18/64 returners (28%) reported later respiratory symptoms during open-water swimming	Later symptoms were self-reported and not uniformly confirmed as SIPE; only 64/152 participants returned

			to open-water swimming
Kristiansson et al., 2026 [30]	Event case-control; 258 cases, 2,117 controls	Largest multivariable analysis of participant characteristics associated with SIPE	Observational; different data collection in cases/controls; approximately 26% control response rate
Seiler et al., 2026 [12]	Prospective event cardiac cohort; 45 cases, 45 controls	Context for post-swim TTE/troponin abnormalities and coexistence of myocardial infarction	Small cohort; subgroup imaging.
Ong et al., 2026 [20]	Qualitative interviews; 17 participants	Symptom perception, concealment, fatigue and cognitive themes relevant to recognition	Self-selected retrospective accounts; not diagnostic criteria
Melau et al., 2019 [21]	Three triathlon cases	Symptoms beginning during swim may be recognized only later in the event	Small retrospective series; not proven late-onset SIPE
Rigler et al., 2022 [11]	Three triathletes with pulmonary edema and Takotsubo	Supports cardiac differential and escalation for chest pain or atypical course	Highly selected; causal direction uncertain
Turris et al., 2017 [16]	Prospective remote-triathlon registry	Integrated water rescue, zoned care, communications, and transport planning	Not SIPE-specific; event-specific staffing; no causal comparison

Table 1 note: Publications from the Vansbro research program overlap in setting, study years, or participants; these cohorts are therefore non-independent and their populations should not be summed.

Abbreviations: CPAP, continuous positive airway pressure; LUS, lung ultrasound; PEP, positive expiratory pressure; SIPE, swimming-induced pulmonary edema; SpO_2, peripheral oxygen saturation; TTE, transthoracic echocardiography.

3.6 Documentation, quality improvement, and research priorities

Good documentation is useful only if it connects what happened to the swimmer with what the medical system did next. For SIPE, a core event record could include the number of exposed participants, timing and circumstances of symptom onset, serial vital signs, key examination findings, treatment and response, recurrence after support was withdrawn, the reason for transfer or discharge, hospital outcome when available, and follow-up. Standardized terminology would make event audits and comparisons easier. What is not known is whether documentation systems, staff training, or formal post-event review themselves improve SIPE outcomes; no comparative study has tested that question [16,45].

The research gaps are mostly practical. Event medicine still lacks a validated case definition, externally tested race-side thresholds, comparative data on oxygen and positive-pressure strategies, and validated observation or discharge criteria. Better studies should link event records to hospital outcomes and follow swimmers prospectively with exposure data rather than relying only on self-reported recurrence. Implementation research is also needed: where resources are placed, how staff are trained, how information moves between teams, and how a service performs when several respiratory cases present at once. Because several publications arise from overlapping Vansbro cohorts, future reports should make participant and study-period overlap explicit.

3.7 Limitations

This review has limitations that follow from both its method and the underlying literature. It was a narrative review with a structured search, not an exhaustive systematic review. Study selection was based on relevance, some potentially eligible reports could not be assessed in full text, and we did not perform a formal risk-of-bias or GRADE assessment. The included evidence spans event cohorts, military and diving studies, physiological experiments, reviews, and case reports, often with different case definitions and outcomes. We also did not review federation rules, organizer manuals, or regulatory standards. The pathway presented here should therefore be read alongside, rather than in place of, local policies and governing documents.

Generalizability is the larger problem. Much of the event-specific evidence comes from a small group of overlapping Vansbro studies conducted in a low-altitude, cold-water environment. LUS identifies pulmonary edema but does not establish its cause, reference standards differ across studies, and treatment evidence is observational. Civilian data from other events remain sparse and are dominated by case series, selected cohorts, surveys, and qualitative work. As a result, the proposed pathway is on firmer ground for recognition, extraction, basic assessment, supportive care, repeated reassessment, and capability-adjusted escalation than it is for exact diagnostic thresholds, treatment selection, or discharge rules.

4. Conclusions

SIPE is uncommon, but even a small number of cases can create a significant operational problem at a mass-participation open-water event. The available event studies support simple race-side measures—pulse oximetry, auscultation, oxygen when indicated, and repeated clinical assessment—and suggest a useful adjunctive role for LUS where trained operators are available. Positive-pressure support can be delivered on site, although current data cannot tell us which technique is superior or who benefits most. Persistent crackles or B-lines may remain after clinical recovery and should not be used in isolation to judge treatment failure or disposition. The main value of the proposed pathway is to connect these observations into a sequence that an event medical service can use and adapt. Multicenter studies with common definitions, linked hospital outcomes, and comparative treatment data are now needed to test the parts of the pathway that remain based largely on expert interpretation and local practice.

Declarations

Author contributions: Conceptualization, J.G. and M.Ł.; methodology, M.Ł., B.B. and J.G.; literature screening and evidence mapping, M.P., J.W., B.B. and J.N.; writing - original draft preparation, M.P., J.G., J.J., J.N., and M.Ł.; writing - review and editing, M.P., J.G., J.J., J.N., and M.Ł.; visualization, M.P. and J.G.; All authors have read and agreed to the submitted version of the manuscript.

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Informed Consent Statement

Not applicable.

Data Availability Statement

No new data were created or analyzed in this study. All data discussed are available in the cited primary studies listed in the references.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used OpenAI ChatGPT to support language refinement, document structuring and formatting, bibliographic-style verification, and consistency checks. The authors reviewed and edited all content, independently verified the cited evidence, and accept full responsibility for the substantive content of the publication.

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