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ORIGINAL ARTICLE

Tendon-Dominant in the Hand, Joint-Dominant in the Foot: The Diagnostic Spectrum of High-Resolution Sonography in 406 Consecutive Small-Joint Referrals

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Abstract

Background and Objectives: Sonographic evidence in small-joint disease derives almost entirely from cohorts assembled around a known diagnosis, which cannot yield base rates for the referral population itself. We characterised the disease spectrum detected by high-resolution sonography in consecutive unselected referrals, and tested whether the anatomical distribution of disease differs between the hand and the foot. **Methods:** Cross-sectional study of 406 consecutive sonographic examinations of the small joints of the hand or foot performed in 355 patients at a tertiary centre (November 2017 to August 2019). Examinations used 5-14 MHz linear and 8-12 MHz hockey-stick transducers with colour Doppler; findings were defined a priori by Outcome Measures in Rheumatology criteria and assigned to joint-, tendon-, soft-tissue- or miscellaneous compartments. Proportions carry Wilson 95% confidence intervals (CI); the regional distribution was compared by chi-square with Cramer V. Reporting follows STROBE. **Results:** Patients were aged 1-85 years (mean 45.6, SD 16.0); 191 of 355 (53.8%) were male. Sonography identified an abnormality in 322 of 406 examinations (79.3%, 95% CI 75.1-83.0). The compartment distribution differed sharply by region (chi-square = 73.9, df = 2, $P < .001$; Cramer V = 0.49): tendon-related disease predominated in the hand (49/89; 55.1%, 95% CI 44.7-65.0) and joint-related disease in the foot (124/219; 56.6%, 95% CI 50.0-63.0), a difference of 40.4 percentage points for tendon disease (95% CI 28.8-51.2). Tenosynovitis was the commonest single diagnosis (57/406; 14.0%, 95% CI 11.0-17.8). Infection accounted for 50 examinations, and the spectrum also included tendon tear, plantar fasciitis, ganglion, lipoma and radiolucent foreign body. Of 26 patients with isolated tenosynovitis investigated for inflammatory arthritis, 14 (53.8%) received a final diagnosis of rheumatoid arthritis. **Conclusions:** Sonography localised the cause of symptoms to a tissue compartment in four of five referrals, across a spectrum reaching well beyond arthritis. Disease distribution is region-dependent, which argues for region-specific protocols and for sonography as a first-line rather than adjunctive investigation.

Keywords: arthritis, foot, hand, high-resolution ultrasonography, musculoskeletal ultrasound, point-of-care ultrasound, small joints, tenosynovitis

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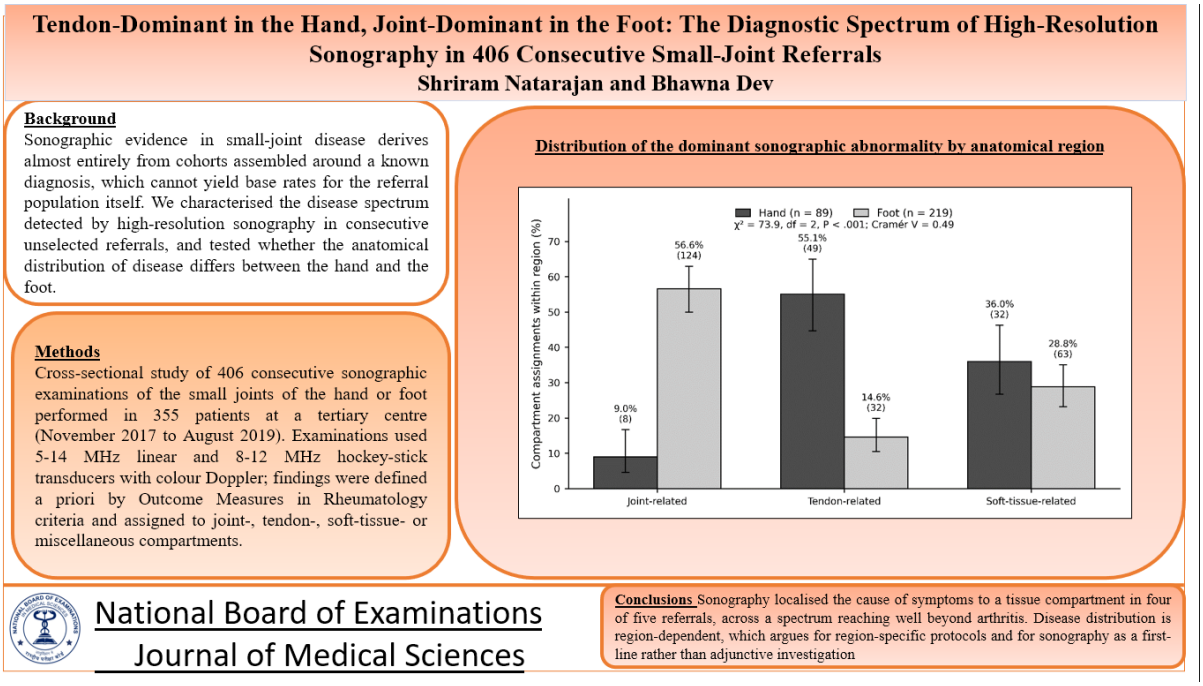
Graphical Abstract



Introduction

Pain and swelling in the small joints of the hand and foot are among the least specific presentations in clinical medicine. The complaint localises poorly, physical examination rarely separates a synovial process from a tendinous or subcutaneous one [1-3], and the investigation ordered first—a plain radiograph—reports on the one tissue that is usually last to change [4,5]. The consequence is a diagnostic sequence in which the initial imaging study is frequently normal and the patient is either reassured prematurely or referred onward for cross-sectional imaging that may be neither affordable nor timely [6].

High-resolution sonography occupies an unusual position in that sequence because it does not respect the anatomical boundary the referral question implies. A probe placed over a painful metacarpophalangeal joint interrogates skin, subcutaneous fat, tendon, sheath, pulley, enthesis, bursa, joint recess, cartilage and cortical surface in a single sweep, and adds a functional dimension—flow on colour Doppler, behaviour under dynamic stress—that no static modality supplies [6]. The physical basis was settled decades ago [7,8], and the descriptive vocabulary has since been standardised through Outcome Measures in Rheumatology (OMERACT) consensus definitions [9] and European scanning protocols [10], so the modality is now reproducible enough to carry clinical weight [11,12].

What has followed that consolidation is a literature organised almost entirely by disease. Sonography has been validated against radiography for erosion detection in rheumatoid arthritis [4], against clinical examination for synovitis [2], against clinical examination again for flexor tenosynovitis [3], as a predictor of progression in undifferentiated arthritis [13], and, in dermatological and surgical practice, for the characterisation of

lipomas, epidermal cysts and ganglia [14]. Plantar fasciitis has its own sonographic literature [15,16], as do hand osteoarthritis [17], connective-tissue disease [18] and crystal deposition [19,20]. Each of these bodies of work begins by selecting patients who already carry the diagnosis under study. That is the correct design for estimating accuracy, but it conditions on the answer, and so produces an evidence base that cannot address the question a referring clinician actually asks. The clinician does not want to know whether sonography detects tenosynovitis in a patient known to have rheumatoid arthritis; the clinician wants to know what a swollen finger of uncertain cause is likely to turn out to be, and whether an ultrasound examination will settle it.

Answering that requires the opposite sampling frame: a consecutive series defined by the referral rather than by the diagnosis, in which the denominator contains the normal studies, the infective and traumatic presentations that never reach a rheumatology clinic, and the incidental mass lesions that arrive under a joint-pain heading. Such cohorts are uncommon, and Indian data are sparser still, despite an adult rheumatoid arthritis prevalence of roughly 0.75% translating into several million people [21] competing for imaging in settings where sonography is often the only musculoskeletal modality immediately available at the point of care.

We therefore analysed 406 consecutive examinations of the small joints of the hand or foot performed at a single tertiary centre, with no restriction by suspected diagnosis. The objectives were to describe the distribution of disease across joint, tendon, soft-tissue and miscellaneous compartments; to test whether that distribution differs between hand and foot in a way that should alter scanning practice; and to identify the presentations in which sonography redirects the diagnostic pathway rather than merely confirming it.

Materials and Methods

Design, setting and reporting

This was a single-centre cross-sectional observational study conducted in the Department of Radiology and Imaging Sciences of a tertiary-care teaching hospital in southern India, with consecutive accrual between November 2017 and August 2019. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (approval number: CSP-MED/17/NOV/40/147). Written informed consent was obtained from every participant in English or Tamil, and from a parent or legal guardian for participants younger than 18 years. The manuscript is reported in accordance with the STROBE statement for cross-sectional studies [22].

Participants and unit of analysis

All patients referred for sonographic evaluation of pain or swelling involving the small joints of the hand or foot during the study window were eligible, irrespective of age, referring specialty or working diagnosis. Patients who had undergone previous surgery at the region of interest, and those in whom an adequate examination was precluded by a cast, an overlying dressing or inability to cooperate, were not enrolled.

The unit of analysis is the examination rather than the patient, because a substantial minority of patients were examined more than once, either at a second anatomical site or at a second time point. In total, 406 examinations were

performed in 355 patients: 304 patients contributed a single examination and 51 contributed two. Demographic characteristics are therefore reported at patient level and all imaging findings at examination level, and each denominator is stated explicitly wherever a proportion is given. No sample-size calculation was performed; the study was designed to characterise a complete consecutive referral stream rather than to test a pre-specified hypothesis, and the sample comprises all eligible examinations performed during the accrual period.

Sonographic technique

Examinations were performed on a Toshiba Aplio 500 Platinum (Canon Medical Systems, Otawara, Japan) and GE Logiq P5, P9 and E platforms (GE Healthcare, Milwaukee, WI) using a 5-14 MHz linear transducer and, for the digits and superficial structures, an 8-12 MHz L-shaped hockey-stick transducer. A stand-off pad constructed from an acoustic-gel-filled glove was used where the structure of interest lay immediately beneath the skin. For hand examinations the patient sat facing the operator with the limb supported on a pillow, which allows the wrist and digits to be rotated freely through extensor, collateral and flexor windows; foot examinations were performed supine with the symptomatic side nearer the operator.

The clinically dominant limb was scanned. Metacarpophalangeal and interphalangeal joints were examined in the hand and metatarsophalangeal joints in the foot, together with skin, subcutaneous tissue, tendons and sheaths, entheses, bursae, digital expansions and flexor pulleys, following established normal sonographic anatomy [23]. Each joint was interrogated in longitudinal and transverse planes, the longitudinal plane serving as the primary assessment and the transverse plane as confirmation; coronal imaging with the digit flexed to 90° was added at the proximal interphalangeal joints. Dynamic flexion was used routinely, since bunching of the synovium into the proximal recess renders conspicuous a degree of hypertrophy that is easily overlooked in the neutral position. The extensor aspect was examined first, then the collateral aspects, then the flexor aspect. Colour Doppler was applied to every region of interest with pulse-repetition frequency and gain set to the lowest values that did not generate motion artefact. Anisotropy was managed by heel-toe angulation, and any hypoechoic focus that resolved with angulation was disregarded.

All examinations were performed and interpreted by a single radiologist with access to the clinical history and to prior imaging using a standardized protocol to ensure methodological consistency. Interobserver reliability was consequently not assessed; this is addressed under Limitations.

Definitions and compartment assignment

Sonographic pathology was defined a priori using OMERACT criteria [9]. Simple effusion was compressible, transonic intra-articular material without Doppler signal; synovial hypertrophy was non-displaceable, poorly compressible intra-articular tissue, graded 0-3 (absent; <2 mm; 2-4 mm; >4 mm); synovial vascularity on colour Doppler was graded 0-3 (absent; isolated vessels; <50% of the synovial area; >50%); tenosynovitis was anechoic or hypoechoic distension of the tendon sheath relative to the tendon fibres; erosion was an intra-articular cortical discontinuity visible in two orthogonal planes; and enthesitis

was entheseal thickening and hypoechogenicity with Doppler signal.

Each examination was assigned to the tissue compartment in which the dominant abnormality lay: joint-related (synovitis, effusion, erosion, crystal deposition, osteoarthritis, bursitis, inflammatory arthritis); tendon-related (tenosynovitis, tendon tear, calcific tendinosis, trigger digit, tendon-associated ganglion); soft-tissue-related (abscess, cellulitis, myositis, subcutaneous oedema, plantar fasciitis, callosity, ulcer, haematoma); miscellaneous (lipoma, haemangioma, vascular malformation, nerve entrapment or thickening, foreign-body granuloma, epidermal inclusion cyst, implantation dermoid); and no sonographic abnormality. In 10 examinations, abnormalities of comparable clinical weight were present in two compartments—for example flexor tenosynovitis coexisting with a joint effusion, or a subcutaneous collection with an underlying tendon tear—and were assigned to both. Compartment assignments therefore exceed the number of abnormal examinations by that margin, and this is stated in the relevant table footnotes rather than concealed by forcing an arbitrary single assignment.

Ancillary data

Erythrocyte sedimentation rate, C-reactive protein, IgM rheumatoid factor, anti-cyclic citrullinated peptide antibody and serum urate were recorded when available from the hospital information system, and prior radiographs were retrieved from the picture archiving and communication system. These ancillary data were incomplete by design, having been requested on clinical rather than research grounds, and are reported with their own denominators.

Statistical analysis

Analyses were performed in SPSS version 17.0 (SPSS Inc., Chicago, IL). Age is summarised as mean with standard deviation and as median with interquartile range, the distribution having been inspected graphically. Categorical variables are presented as counts with percentages and Wilson score 95% confidence intervals, which are preferred to the normal-approximation interval at the small cell counts encountered among the rarer diagnoses; differences between two proportions are given with Newcombe hybrid-score confidence intervals.

The primary comparison—the distribution of the three principal tissue compartments between hand and foot examinations—was tested by the Pearson chi-square test, with the strength of association expressed as Cramer V and the source of the association localised through standardised residuals; residuals exceeding ±2 identify cells contributing disproportionately to the overall statistic. Two-sided P values below .05 were considered significant. The analysis was performed with available case and no imputation was undertaken. Analyses of individual diagnoses are descriptive and hypothesis-generating; no correction for multiplicity was applied and these estimates are interpreted as such rather than as confirmatory tests.

Results

Cohort

A total of 406 examinations were performed in 355 patients (Figure 1 and Table 1). Patients were aged 1 to 85 years (mean 45.6, standard deviation 16.0;

median 46, interquartile range 36-57), and 191 of 355 (53.8%, 95% CI 48.6-58.9) were male. The distribution was broad but weighted towards middle age, with 235 of 355 patients (66.2%) aged between 31 and 60 years. Referrals concerned the foot considerably more often than the hand, in a ratio of approximately three to one.

Table 1. Characteristics of the study cohort

Characteristic	Value
Patients, n	355
Examinations, n	406
Patients contributing one examination, n (%)	304 (85.6)
Patients contributing two examinations, n (%)	51 (14.4)
Male, n (%)	191 (53.8)
Female, n (%)	162 (45.6)
Sex not recorded as male or female, n (%)	2 (0.6)
Age, mean ± SD, years	45.6 ± 16.0
Age, median (IQR), years	46 (36–57)
Age, range, years	1–85
Age ≤30 years, n (%)	59 (16.6)
Age 31–60 years, n (%)	235 (66.2)
Age >60 years, n (%)	61 (17.2)

SD, standard deviation; IQR, interquartile range.

Demographic characteristics are reported at patient level (n = 355); all imaging findings are reported at examination level (n = 406).

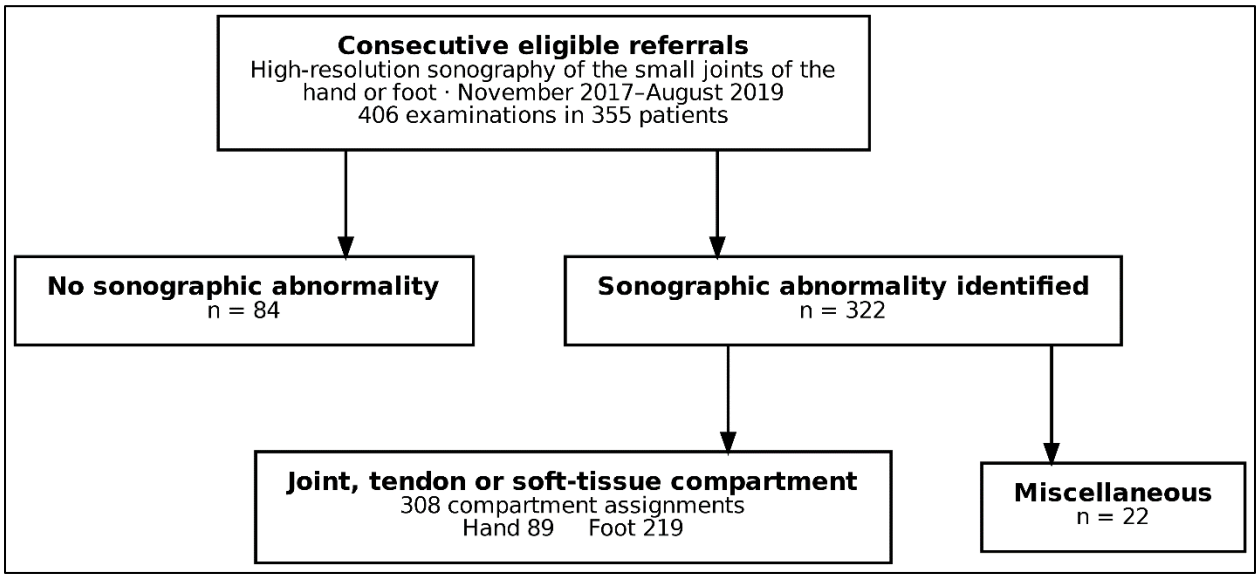


Figure 1. Flow of examinations through the study

Yield of the examination

Sonography demonstrated an abnormality in 322 of 406 examinations (79.3%, 95% CI 75.1-83.0); 84 studies (20.7%, 95% CI 17.0-24.9) were normal. The abnormalities encountered spanned the full width of the periarticular soft-tissue envelope and were, in aggregate, only partly rheumatological (Table 2). Tenosynovitis was the commonest single diagnosis, present in 57 examinations (14.0%, 95% CI 11.0-17.8). Urate-related crystal disease accounted for 71 examinations (17.5%, 95% CI 14.1-21.5) and rheumatoid arthritis for 17 (4.2%, 95% CI 2.6-6.6). Infection was conspicuous: abscess was identified in 28 examinations and cellulitis in 22, together 50 of 406 (12.3%, 95% CI 9.5-15.9)—a substantial fraction of a referral stream ostensibly directed at joint disease, and one in which the distinction between a drainable collection and diffuse phlegmon carried immediate surgical consequence.

Table 2. Sonographic diagnoses across the cohort (N=406)

Diagnosis	n	% (95% CI)*
No sonographic abnormality	84	20.7 (17.0–24.9)
Tendon and sheath		
Tenosynovitis	57	14.0 (11.0–17.8)
Ganglion cyst	13	3.2 (1.9–5.4)
Tendon or pulley tear (all partial)	11	2.7 (1.5–4.8)
Trigger digit	2	0.5 (0.1–1.8)
Calcific tendinosis	2	0.5 (0.1–1.8)
de Quervain tenosynovitis	2	0.5 (0.1–1.8)
Joint		
Urate-related crystal disease	71	17.5 (14.1–21.5)
Rheumatoid arthritis	17	4.2 (2.6–6.6)
Inflammatory arthritis, unclassified	13	3.2 (1.9–5.4)
Erosion without other joint finding	8	2.0 (1.0–3.8)
Bursitis	8	2.0 (1.0–3.8)
Joint effusion, isolated	8	2.0 (1.0–3.8)
Osteoarthritis	4	1.0 (0.4–2.5)
Calcium pyrophosphate deposition disease	2	0.5 (0.1–1.8)
Soft tissue		
Abscess	28	6.9 (4.8–9.8)
Cellulitis	22	5.4 (3.6–8.1)
Subcutaneous oedema	14	3.4 (2.1–5.7)
Plantar fasciitis	12	3.0 (1.7–5.1)
Haematoma	5	1.2 (0.5–2.9)
Callosity or plantar fibroma	5	1.2 (0.5–2.9)
Myositis	4	1.0 (0.4–2.5)
Miscellaneous		
Lipoma	7	1.7 (0.8–3.5)

Diagnosis	n	% (95% CI)*
Haemangioma or vascular malformation	5	1.2 (0.5–2.9)
Carpal tunnel syndrome	4	1.0 (0.4–2.5)
Foreign body or foreign-body granuloma	3	0.7 (0.3–2.1)
Epidermal inclusion cyst	1	0.2 (0.0–1.4)
Implantation dermoid	1	0.2 (0.0–1.4)
Ulnar nerve thickening	1	0.2 (0.0–1.4)
Lymphoedema	1	0.2 (0.0–1.4)

*CI, confidence interval (Wilson score).

Ganglion cyst: 9 of 13 were tendon-associated.

Diagnoses are not mutually exclusive: 10 examinations disclosed abnormalities in more than one compartment (for example tenosynovitis with joint effusion, or a subcutaneous collection with an underlying tendon tear) and are counted under each; percentages therefore sum to slightly more than 100%. Mass lesions were not confirmed histologically and are sonographic diagnoses.

Beyond infection and arthritis the spectrum included tendon tear (11 examinations, all partial and all managed conservatively), plantar fasciitis (12), ganglion cyst at any location (13, of which 9 were tendon-associated), subcutaneous oedema (14), lipoma (7), haematoma (5), callosity or plantar fibroma (5), haemangioma or vascular malformation (5), carpal tunnel syndrome (4), myositis (4), foreign body (3), and single instances of epidermal inclusion cyst, implantation dermoid, ulnar nerve thickening and lymphoedema. Trigger digit was diagnosed twice, in each case by demonstrating altered echotexture of the flexor digitorum profundus with thickening of the A1 pulley (Figure 2), and de Quervain tenosynovitis twice. In one patient a radiolucent foreign-body granuloma of the thenar eminence was identified as a shadowing echogenic focus that had been invisible on radiography. Histopathological confirmation was not obtained for the mass lesions, which are therefore sonographic diagnoses.

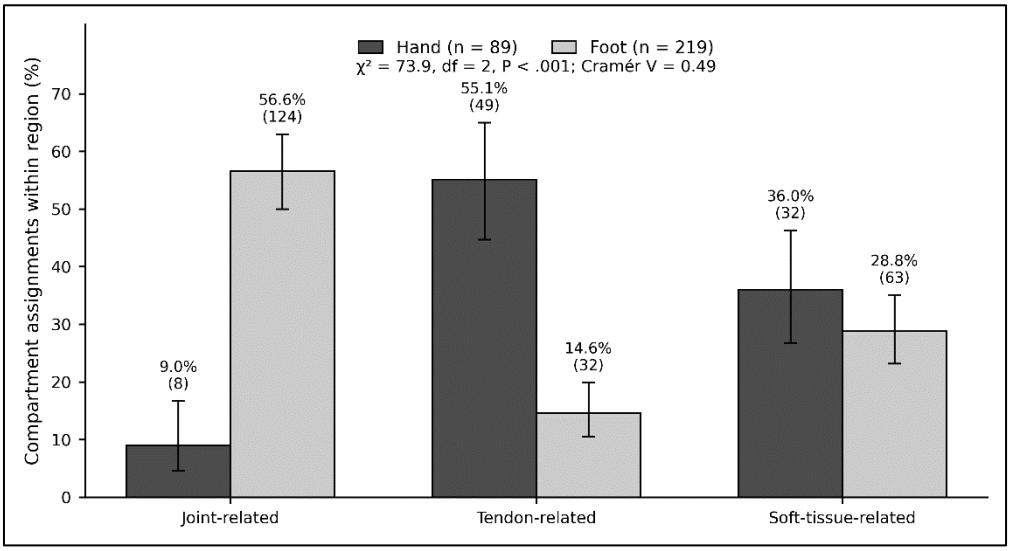


Figure 2. Distribution of the dominant sonographic abnormality by anatomical region.

Regional distribution of disease

The compartment in which disease was found depended strongly on which region was scanned (Table 3, Figure 3). Among the 308 compartment assignments in which the dominant abnormality lay in the joint, tendon or soft tissue, tendon-related disease accounted for 49 of 89 hand assignments (55.1%, 95% CI 44.7-65.0) but only 32 of 219 foot assignments (14.6%, 95% CI 10.5-19.9), a difference of 40.4 percentage points (95% CI 28.8-51.2). The joint compartment showed the mirror image: 124 of 219 in the foot (56.6%, 95% CI 50.0-63.0) against 8 of 89 in the hand (9.0%, 95% CI 4.6-16.7), a difference of −47.6 percentage points (95% CI −55.4 to −37.4). Soft-tissue disease was distributed similarly in both regions (36.0% versus 28.8%; difference 7.2 percentage points, 95% CI −4.0 to 19.0). The overall distribution differed significantly between regions (chi-square = 73.9, df = 2, P < .001), and the association was of moderate-to-large strength (Cramer V = 0.49). Standardised residuals localised the effect precisely to the two reciprocal cells: tendon disease in the hand (+5.3) and joint disease in the hand (−4.9), with the corresponding foot cells at −3.4 and +3.1 and the soft-tissue cells contributing negligibly (+0.9 and −0.6).

Table 3. Distribution of the dominant sonographic abnormality by anatomical region

Compartment	Hand (n = 89), n (%)	Foot (n = 219), n (%)	Difference, pp (95% CI)
Joint-related	8 (9.0)	124 (56.6)	−47.6 (−55.4 to −37.4)
Tendon-related	49 (55.1)	32 (14.6)	+40.4 (+28.8 to +51.2)
Soft-tissue-related	32 (36.0)	63 (28.8)	+7.2 (−4.0 to +19.0)

CI, confidence interval; pp, percentage points.

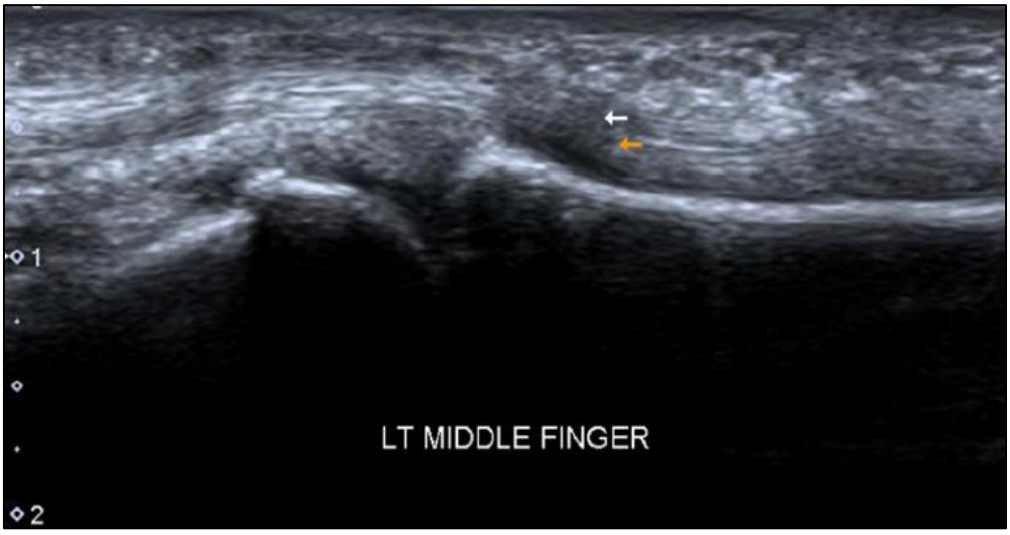


Figure 3. Trigger digit in a 36-year-old woman with painful catching of the left middle finger
*Longitudinal sonogram showing altered echotexture of the flexor digitorum profundus tendon with hypoechoic thickening of the A1 pulley overlying the metacarpal head (arrow).

Joint-related diagnoses were correspondingly concentrated in the foot, where crystal-related disease was the largest single group and the first metatarsophalangeal joint the commonest site of positive findings (Table 4). Six patients in the crystal-arthropathy subgroup had a final diagnosis of calcium pyrophosphate deposition disease, of whom only two were identified prospectively on sonography; the remainder were reported as urate disease.

Tenosynovitis as a forerunner of inflammatory arthritis

In 56 examinations tenosynovitis was the only abnormality demonstrated. In total, 26 of these patients were investigated for suspected rheumatoid arthritis on clinical and serological grounds, and 14 (53.8%, 95% CI 35.5-71.2) ultimately received that diagnosis. The subgroup was defined by clinical suspicion rather than prospectively, so this proportion is conditional on having been investigated and is not a positive predictive value for tenosynovitis at large; the outcome of the remaining 30 patients with isolated tenosynovitis was not systematically ascertained. Read with that constraint, the observation is nonetheless material: half of the patients in whom isolated sheath inflammation prompted a rheumatological work-up proved to have rheumatoid arthritis.

Table 4. Joint-related sonographic diagnoses by anatomical region (N=131)

Diagnosis	Hand, n	Foot, n
Urate-related crystal disease	2	69
Rheumatoid arthritis	5	12
Inflammatory arthritis, unclassified	0	12
Joint effusion, isolated	0	8
Bursitis	0	8
Erosion without other joint finding	0	8
Osteoarthritis	0	4
Calcium pyrophosphate deposition disease	0	1
Erosive arthritis	0	1
Metacarpophalangeal subluxation	1	0
Total joint-compartment assignments*	**8**	**123**

*Counts are joint-compartment assignments and correspond to the joint-related row of Table 2. A count of 0 indicates no case in that region.

Discussion

The central finding of this study is not that sonography detects disease—that much is established—but that what it detects depends on where the probe is placed, in a way the referral question does not anticipate. Hands referred for joint pain overwhelmingly harboured tendon disease; feet referred for the same complaint overwhelmingly harboured joint disease. The effect is large rather than marginal (Cramer V = 0.49), and the standardised residuals show that it is not a diffuse difference in case mix but a specific

reciprocal inversion of the tendon and joint compartments. A single scanning protocol applied uniformly to both regions will therefore be systematically misdirected in one of them.

This asymmetry has an anatomical and biomechanical rationale rather than being an artefact of referral. The digital flexor apparatus of the hand is a high-excursion, pulley-constrained system in which the tendon and its sheath, not the joint, absorb the mechanical and inflammatory load; the synovial sheath is also the largest synovium-lined surface in the hand and is correspondingly the tissue most exposed in early inflammatory disease. The forefoot, by contrast, is a weight-bearing, low-excursion structure in which the first metatarsophalangeal joint sustains repeated high compressive load in a relatively cool, acidic and poorly perfused environment that favours urate crystal nucleation. That soft-tissue disease was the one compartment distributed evenly between regions supports this reading: infection and oedema are not governed by joint biomechanics and would not be expected to show regional preference, and they did not.

Our findings both extend and complicate the existing literature. The disease-specific studies that underpin musculoskeletal sonography have consistently shown superiority over radiography and close agreement with magnetic resonance imaging within their chosen diagnosis—for erosion detection and disease-activity correlation in rheumatoid arthritis [4,24], for synovitis [2], for flexor tenosynovitis [3,25] and its extensor counterpart [26], for de Quervain disease [27], for plantar fasciitis [15,16] and for soft-tissue masses [14] and our unselected series is compatible with each of them taken individually. What an unselected series supplies is the base rate. When patients are not pre-sorted by diagnosis, one in five scans is normal, one in seven shows tenosynovitis, and one in eight shows infection rather than arthritis at all. None of these proportions can be recovered from the disease-specific literature, because that literature conditions on the answer. The practical consequence is that the pre-test reasoning brought to a small-joint referral should be re-anchored: the likeliest explanation for a painful digit arriving in a radiology department is not the arthritis named on the request form.

The tenosynovitis observation is where our data intersect most directly with a contested question. Hmamouchi and colleagues argued that clinical examination is specific but insensitive for flexor tenosynovitis and that sonography should be reserved for the clinically negative patient [3]; Sahbudin and colleagues went further, showing that sonographically defined tenosynovitis carries independent predictive weight for the subsequent development of rheumatoid arthritis over and above synovitis and serology [13]. In our cohort, 14 of the 26 patients with isolated tenosynovitis who were investigated for inflammatory arthritis received that diagnosis. We are deliberate about what this can and cannot mean: the denominator is clinically enriched, so 53.8% is not a positive predictive value, and the confidence interval (35.5-71.2) is wide. What survives those caveats is a directional signal concordant with Sahbudin, and a practical corollary—a report of isolated flexor tenosynovitis in a patient with polyarticular symptoms is not a benign endpoint but an indication for serological work-up.

The mirror image of that argument, and the least flattering result in this series, is the calcium pyrophosphate group: of six patients with an eventual diagnosis of pyrophosphate disease, only two were identified prospectively, the remainder being reported as urate disease. The discriminating feature is real and well described—urate crystallises on the cartilage surface, producing a continuous hyperechoic line parallel to and separate from the subchondral bone, whereas pyrophosphate is deposited within the cartilage substance, producing a discontinuous intrasubstance line [19,20] but it is a distinction of a few tenths of a millimetre in the depth at which an echogenic interface sits, and our experience indicates that it is not reliably reproducible by a single operator at ordinary clinical throughput. Loffler and colleagues reached the same conclusion and recommended that the double-contour sign never be interpreted in isolation [19]. This is a limitation of the modality as it is actually used, not merely of this study, and it should temper enthusiasm for sonography as a stand-alone crystal-typing tool.

Three clinical implications follow. Sonography should be positioned as the first-line examination in small-joint referral rather than as an adjunct ordered after a normal radiograph, since the tissues that most often account for the symptom—tendon sheath, subcutaneous plane, fascia—are radiographically invisible, and since a normal sonogram carries far more information than a normal radiograph. The scanning protocol should be region-specific: a hand protocol that does not sweep the full flexor and extensor apparatus in both planes will miss the commonest finding in that region, and a foot protocol weighted towards the tendons will miss the commonest finding in that one. And the modality is inherently a point-of-care technology: the same equipment that establishes the diagnosis performs the guided injection, aspiration or drainage that follows, and can be repeated at every review without cumulative radiation burden or incremental cost (Figure 4). In a health system where magnetic resonance imaging is neither universally accessible nor rapidly obtainable, that consolidation of diagnosis, intervention and follow-up into one inexpensive examination is arguably the strongest argument for its adoption.

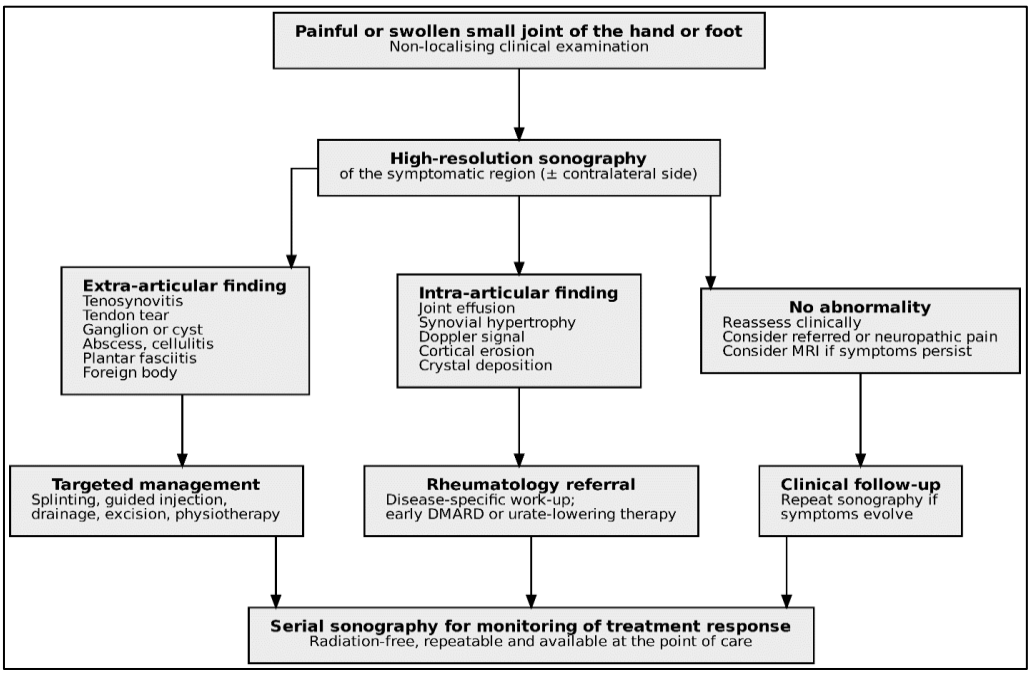


Figure 4. Proposed diagnostic pathway for high-resolution sonography in small-joint referral.

Strengths

The principal strength is the sampling frame. Consecutive, unselected accrual over 22 months with no restriction by suspected diagnosis yields a denominator that reflects real referral practice—precisely the quantity that disease-selected studies cannot supply. All findings were defined a priori against OMERACT criteria [9], so the categories are transportable. Reporting the examination rather than the patient as the unit of analysis, and stating both denominators explicitly, avoids the double-counting that repeat examinations would otherwise introduce. Single-operator interpretation, though a limitation for reliability, removes between-reader variation as a source of heterogeneity in the descriptive estimates.

Limitations

Several constraints bound the inferences. The study is single-centre and hospital-based, so the case mix reflects the referral behaviour of one tertiary institution; the prevalence of infection and mass lesions would almost certainly be lower in primary care. Because one reader performed and interpreted every examination, interobserver agreement could not be estimated and no kappa statistic is available; the reproducibility of these categories in other hands is untested, and the learning curve described by D'Agostino and colleagues [2] suggests it is not trivial. There was no independent reference standard for most diagnoses: mass lesions were not confirmed histologically, and infective and inflammatory diagnoses rested on the composite of clinical course, laboratory data and treatment response rather than on tissue. The number of patients excluded before enrolment on grounds of previous surgery or inadequate access was not logged prospectively, so a formal STROBE exclusion count cannot be given. Laboratory and radiographic data were obtained for clinical rather than research

purposes and are incomplete, with denominators that vary between analyses. Finally, follow-up was neither systematic nor of uniform duration, which precludes any statement about the effect of sonographic diagnosis on hard outcomes; the management consequences described here are inferences from diagnostic information, not measured outcomes.

Future directions

The obvious next study is prospective, multi-reader and outcome-anchored: a consecutive referral cohort scanned independently by two readers, with pre-scan and post-scan management plans recorded, would supply both the reliability estimate this study lacks and a direct measure of the change in management that sonography produces—the quantity that health systems, rather than radiologists, will want to see. A second priority is the crystal-typing problem: if the discrimination between surface and intrasubstance deposition sits at the resolution limit of routine grey-scale imaging, then either standardised acquisition with a defined insonation angle, or a quantitative reference such as dual-energy computed tomography, will be needed to establish where the boundary of reliable sonographic distinction actually lies. Third, the predictive weight of isolated tenosynovitis deserves a dedicated prospective cohort with defined follow-up in which the endpoint is fulfilment of classification criteria rather than a retrospectively assembled clinical diagnosis.

Conclusions

In an unselected referral population, high-resolution sonography localised the cause of small-joint symptoms to a specific tissue compartment in four of every five examinations, across a spectrum reaching well beyond arthritis into infection, tendinopathy, trauma and mass lesions. The distribution of that disease was strongly region-dependent—tendon-dominant in the hand, joint-dominant in the foot—which argues for region-specific scanning protocols rather than a single generic examination, and supports positioning sonography as the first-line imaging investigation for small-joint symptoms, with radiography reserved for the questions it answers well.

Statements and Declarations

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No funding was received for conducting this study.

Conflicts of interest

The authors declare that they do not have conflict of interest.

Ethical Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (approval number: CSP-MED/17/NOV/40/147).

Informed Consent

Written informed consent was obtained from every participant in English or Tamil, and from a parent or legal guardian for participants younger than 18 years.

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