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ORIGINAL ARTICLE

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An 810 nm diode laser in the treatment of small (≤ 1.0 mm) leg veins: a preliminary assessment

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Abstract A consistently effective treatment for small leg veins (≤ 1.0 mm) is still being sought. The efficacy of an 810 nm diode laser in vein removal was assessed in a preliminary study. Fifteen females, skin types I to III, vein diameters 0.5–1 mm, aged from 25 to 42 years, participated in the study. An 810 nm diode laser (90 W, 20 ms/pulse, 10 Hz rep rate, 4.0 mm hand piece) was applied along the target veins. Biopsies were taken from two patients before and after the first treatment session. No compression was applied post-treatment. Four weeks later, a second treatment was given. Results were assessed subjectively from the patients' satisfaction index (SI) and objectively from clinical photography done by an independent clinician, who also judged the venous morphology before and 4 weeks after the second session. All patients completed the trial. Pain was moderate to severe at the time of treatment and erythema which was mild, which was seen in all 15 patients; oedema occurred in 12 patients and blistering in only one. No scarring was noticed. The overall satisfaction indices at the 4- and 8-week assessments were 20.7% and 55.1%, respectively. No patient got worse. The objective evaluations at the 4- and 8-week assessments showed increasing improvement in all aspects examined. Pain at the time of treatment was a problem for all patients, so epidermal cooling should be added. Despite this, the 810 laser diode was an interesting and promising device for treatment of small leg veins, warranting further study in larger patient cohorts with a longer-term follow up.

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Introduction

The treatment of small leg veins (≤ 1.0 mm in diameter) is still a subject for debate, although good results have been reported in vessels up to 1 mm using visible light lasers [1, 2]. Visible light lasers are however quite expensive and this may prohibit their purchase in the smaller ractice, unless one is already present for the treatment of other pathologies. There is thus a need for smaller, more portable and less expensive systems to treat these small but troublesome vessels. We evaluated in a preliminary study the use of an 810 nm diode laser for this indication.

Subjects and methods

Patients

Fifteen female patients matched the entry criteria and were enrolled in the study, after being informed of the purpose of the study and signing consent forms for both the study and for clinical photography. Three patients were skin type I, five type II and seven type III. There were eight patients with veins of approximately 0.5 mm in diameter, and seven with 1 mm diameter veins (Table 1). Inclusion criteria were skin types I to II inclusive; and the presence of red, light-blue and blue veins of the lower extremities with diameters not exceeding 1 mm. Exclusion criteria were: pregnancy or nursing, presence of any inflammatory skin disease, recent sun tanning and open wounds in the area to be treated.

Laser system

The laser system was a semiconductor laser, MedArt 435 (Asah Medico, Hvidovre, Denmark), producing 90 W in a continuous wave at 810 nm, delivered via an optical fibre to a hand piece giving a 4 mm diameter beam at the tip of the guide post, producing incident irradiance per

Table 1 Age, skin type and vessel diameter of patients

Patient No.	Age	Skin type	Vessel Diameter	Patient No.	Age	Skin type	Vessel Diameter
1	25	III	0.5 mm	9	29	I	0.5 mm
2	28	II	0.5 mm	10	31	II	0.5 mm
3	32	I	1.0 mm	11	28	III	0.5 mm
4	27	II	1.0 mm	12	25	I	0.5 mm
5	38	III	1.0 mm	13	42	III	1.0 mm
6	33	II	1.0 mm	14	33	III	1.0 mm
7	30	II	0.5 mm	15	29	III	0.5 mm
8	42	III	1.0 mm	-	-	-	-

shot of approximately 716 W/cm^2. A pulse width of 20 ms at a repetition rate of 10 hz was chosen, giving an incident radiant fluence per individual pulse of around 14 J/cm^2. A visible red aiming beam (diode laser, 635 nm) was confocal with the invisible 810 nm treatment beam. No cooling or anesthesia was used.

Treatment protocol

All subjects were instructed to shave before treatment, as the 810 nm beam might be absorbed in the hair above the skin surface, burning them, thereby injuring the surface of the skin, and at the same time preventing all the available energy of the beam from reaching the target area. The target veins were first compressed by a prototype device developed by the first author (MAT) (Fig. 1), which consisted of a flat O-ring plate attached to a handle and a piston with exactly the same diameter as the internal diameter of the O-ring (Fig. 1a). The piston was placed inside the O-ring, and applied with pressure to the area of interest (Fig. 1b). The O-ring was then slid down the piston and applied to the tissue with pressure, together with the piston, for a few seconds (Fig. 1c), thereby forcing most of the blood out of the veins and flattening them. With pressure being maintained on the O-ring, the piston was then removed revealing the target area, with a slight convex extrusion of the overlying skin in the centre of the O-ring (Fig. 1d). The laser was then activated, moving the hand piece positioned perpendicularly to the tissue at a slow but steady rate along the path of the target vein (Fig. 1e). After the treatment was complete, a cream containing 0.25% prednicarbate {a synthetic corticosteroid, 11β, 17, 21-trihydroxypregna-1,4-diene-3,20-dione 17-[ethyl carbonate 21]-propionate} was applied gently to the treated area, no compression dressing was applied. The patients then returned 4 weeks later for a second identical treatment.

Clinical photography

Under the same conditions of ambient light, high-resolution digital photography (Sony Mavica MVC-FD91) was taken without any flash before and after the first session, at the 4-week assessment (before the second treatment session), and at the 8-week assessment (4 weeks after the second session). The data for each patient were kept on individual floppy diskettes, which also ensured consistency in focal distance and target area.

Histological assessment

Punch biopsies (2 mm) were taken from two volunteer patients as a cross-section, immediately before and immediately after the first session to assess the immediate effect of this system on vessels of both sizes. Specimens were routinely fixed and sent for blinded histological analysis with hematoxylin and eosin staining.

Subjective assessment

All 15 patients underwent interviews with the same clinician at the 4- and 8-week assessments regarding their satisfaction with the macroscopic resolution of their

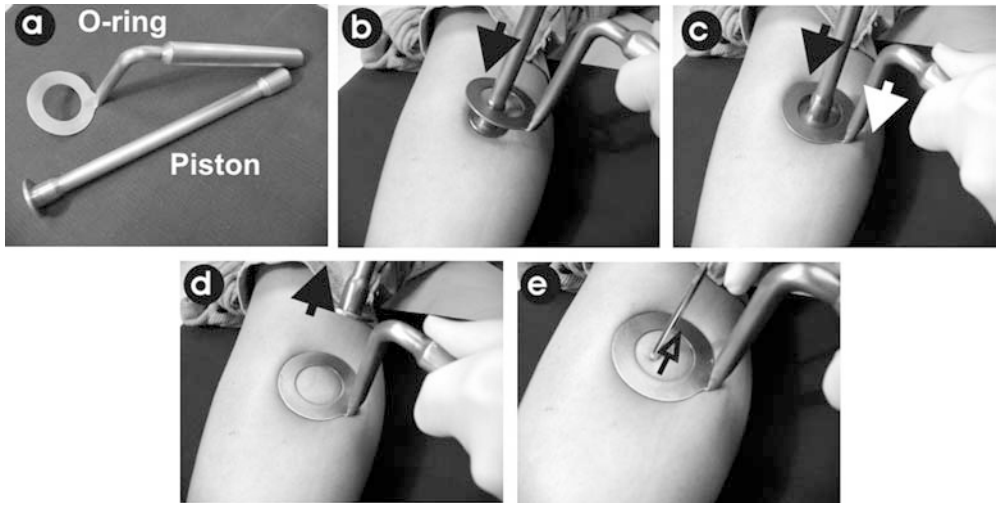


Fig. 1a–e The prototype vessel compressor used in the study seen in action on a volunteer subject. **a** Component parts of the compressor; **b–d** shows the piston inserted in the O-ring pressing the treatment area. When piston is removed the O-ring maintains pressure at the time that the laser is pulsed (**e**)

veins. They graded their satisfaction on a five-level scale; 'very satisfied', 'satisfied', 'fairly satisfied', 'dissatisfied' and 'worse'. The 'very satisfied' and 'satisfied' scores were totaled to give the overall satisfaction index (SI).

Objective assessment

The objective assessment was carried out by an independent clinician not involved in the study and was based on the clinical photography before treatment and at the 4- and 8-week assessments, in addition to physical examination and palpation of the target veins at the same points. The results were compared with the pretreatment findings from four aspects: age-related melanin anomalies, color change in the veins, and morphology of the veins assessed by careful palpation and for checking the softness of the skin over the veins. Finger pressure was applied the veins to test for any sign of continued flow or for complete coagulation.

Results

All subjects completed the entire study protocol. All 15 patients complained of moderate to severe pain at the moment of the treatment, which subsided immediately afterwards. No patient refused further treatment. All subjects were pain-free during the 4 weeks leading up to each of the assessment points. Erythema which was mild in all subjects, lasting from 10–20 days after each treatment, and oedema was reported in 12 patients, lasting approximately 1 week after each treatment. No significant difference was seen in either of these sequelae between the first and second sessions. Blistering was seen in only one patient after the first session, but not the second, which completely resolved without atrophie blanche and with no other sequelae. No hyper-, hypopigmentation or scarring was seen after either session.

Patients subjectively assessed clearing of their veins with an overall SI score of 20.7% at the 4 week-assessment, which had improved to 55.1% at the 8-week assessment, consisting of the 'very satisfied' plus the 'satisfied' scores (Table 2). The number of 'dissatisfied' patients dropped at the 8-week- compared with the 4-week assessment, as did the number of 'fairly satisfied' patients (Fig. 2).

The objective clinician's assessment based on the clinical photography and pressure on the treated veins produced the results for the four items mentioned above (Fig. 3). As with the patient SI scores, there was an improvement seen between the 4-week and the 8-week assessments, except for a very slight decrease in the improvement noted in age-related melanin anomalies. Particularly good improvements were noted in the resolution of the veins both by color and by testing via pressure on the vessel and to check skin integrity. Better results were seen overall in the blue and light-blue than in the red vessels, although the latter also cleared reasonably well.

Histological assessment with HE staining showed typical veins pretreatment (representative examples in Fig. 4a indicated by arrows) which had collapsed completely surrounded by mildly coagulated tissue immediately after the first treatment session (open arrowheads in Fig. 4b). In fact, the post-treatment biopsy was taken first, immediately after treating a portion of the vein, and care was take to biopsy the same vein at an untreated site to show comparative histologies. Bleeding

Table 2 Subjective patient satisfaction scores and overall satisfaction index (SI) obtained by adding 'very satisfied' and 'satisfied' scores

SI Grading	4-week Assessment		8-week Assessment	
	N	Overall SI	N	Overall SI
Very satisfied	–	-	1	-
Satisfied	3		8	
Somewhat satisfied	8	20.7%	4	55.1%
Dissatisfied	4	-	2	-
Worse	–	-	–	-

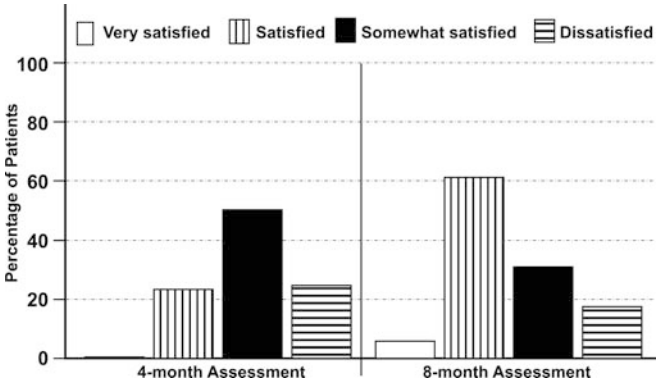


Fig. 2 Bar graph showing the patient SI scores expressed as a percentage compared for the 4-week and 8-week assessments

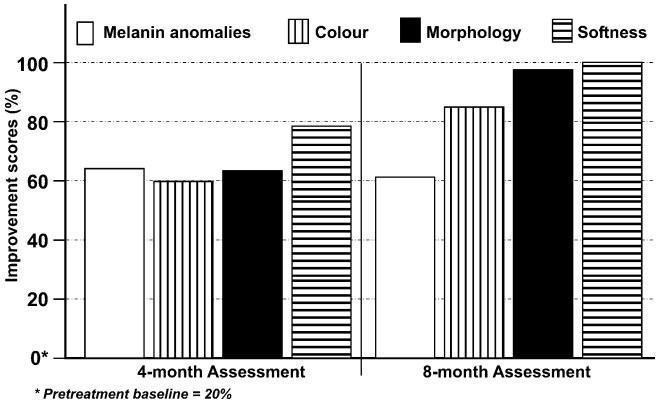


Fig. 3 Bar graph showing objective clinician assessment of treatment efficacy for the items examined compared for the 4-week and 8-week assessments

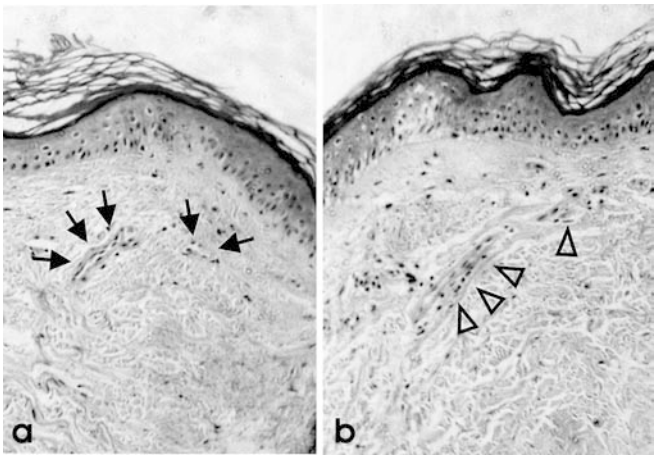


Fig. 4a, b Histological findings. **a** Pretreatment histology shows typical small veins in the upper dermis before treatment (*arrows*). **b** The condition of similar veins post-treatment, showing vessel collapse with mild coagulation in the surrounding dermis demonstrated by a gradual change from basophilic to eosinophilic tissue. (Skin, H&E: original magnification ×200)

was noticed at the untreated site but not at the treated site. No biopsies were taken at the second treatment session.

An area under treatment on the thigh of a 42-year-old female, skin type III is shown in figure 5a. The impression of the O-ring compressor is clearly seen to the right of the illustration, with the immediate post-treatment findings seen in the center of the ring. The area to the left of the ring markings is untreated. The impression allows accurate placement of subsequent shots without overlapping. Note the presence of the vessel very close to the surface of the skin (arrow). Figure 5b shows the findings at the 4-week assessment, before the second treatment. Where the very superficial vein was, there is now a blister due to the reflux of heat from that vein to the epidermis during treatment. Some clearing of the other veins is seen compared with figure 5a. The result at the 8-week assessment is seen in figure 5c. Despite the presence of the small blister, now healed well, the result as far as the clearance of the veins is very good.

Fig. 5a–c 42-year-old female, skin type III, with small leg veins on her thigh. **a** An O-ring impression is seen on the right of the figure, showing the immediate post-treatment condition. Untreated veins are seen to the left of the impression (*arrow*). **b** Findings at the 4-week assessment. Some clearing has occurred, but a blister has appeared at the site of the superficial vessel. **c** Very good result at the 8-week assessment. The small blister healed well without atrophie blanche

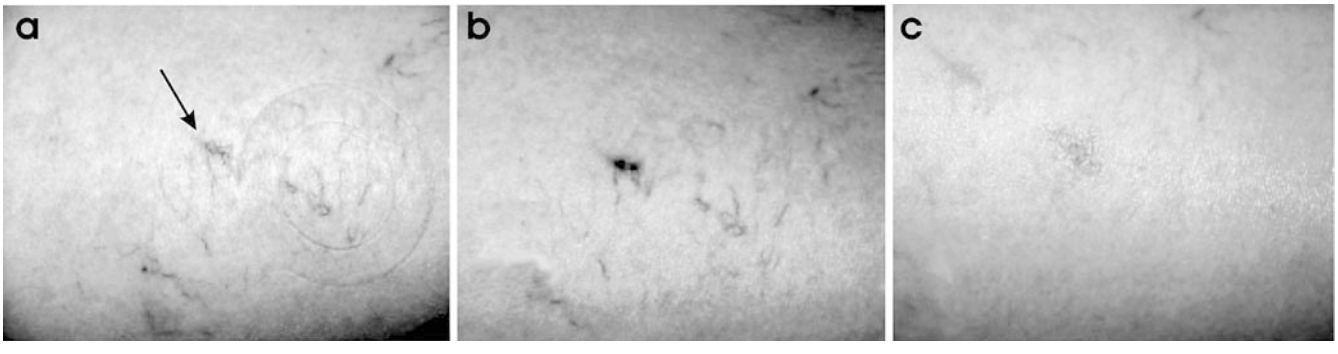
Discussion

Lasers, particularly those operating in the green waveband have been used with some success in clearing veins up to 1 mm in diameter, [1, 2], but there is the high possibility that some epidermal damage will result [3].

The 810 nm wavelength is minimally absorbed in water, so the dermis and to a lesser extent the epidermis are not a problem when considering the penetration depth of this system down to around 600–800 μm to reach the vessels in the papillary and upper reticular dermis [3]. Despite what has been stated in the literature, this wavelength has very little pigment specificity per se, i.e., in melanin and hemoglobin, with the real chromophore being protein. Both melanin and hemoglobin also contain protein, however, the latter more than the former, so they are still targets for the 810 nm beam, but not as far as pigment specificity is concerned [4]. Compared with the dermis, the epidermis is comparatively lower in protein substances, whereas the dermis, including the vessel walls and the blood within their lumina, is rich in proteins. This means that the superficial vessels which form the collections of target vessels up to around 1 mm in diameter form a very good target for the 810 nm wavelength, whereas the epidermis will not absorb the 810 nm beam to the same extent.

Comparatively better results were seen in the blue compared with the red vessels: this might be related to the difference in vessel caliber and in their hemodynamics, particularly the blood flow rate as our group reported in 1996 [5]. The faster the blood flow the better the natural cooling power of the vessels, and the slower the progressive heat build-up necessary for good coagulation.

The compression device used in this study flattens the vessels beneath it, so that the walls are brought into contact. Thus, good luminal welding of the vessel walls through mild coagulation and protein degradation can be achieved, plus the possible activation of heat shock



protein 70 (Hsp 70) which is believed to participate in accelerating the healing process [6].

If the delivered thermal damage is not too high, the wound healing process will result in a more gentle fibrogenetic process giving a dense layer of collagen over the target vessels, in effect, a structured dermal scar, invisible macroscopically, under an intact epidermis [7]. The ideal result of this would be a collagenous optical filter, which will firstly absorb more of the light incident on the area of interest, and then will secondly absorb the light reflected from the vessels back towards the eye of the viewer, thus giving a normal colour to the area of interest, even though some recanalization may have occurred in the vessel (Fig. 6).

Previous reports on the 810 nm diode laser have suggested that the results in small vessels gave minimal improvement, although on the positive side there was no tissue damage, a typical example being the study by Varma and Lannigan [8]. This study presented a regimen involving four treatments at 4-week intervals, 35 W, 100 ms shots with a 0.5 s interval, delivering a maximum radiant flux per shot of 17.8 J/cm^2. The authors suggested that a higher fluence might well prove more effective. In our study, although the fluence per shot was slightly less, the irradiance, or power density, was higher, delivered over a 20 ms pulse width, five times shorter than the previous study, and at a higher repetition rate, of 10 shots/s, with only two treatments, 4 weeks apart. The energy was therefore delivered in a train of comparatively short 20 ms shots with a comparatively large 200 ms interpulse interval, around 10 times the pulse width, thus allowing some degree of intershot cooling to occur before the next shot, while still maintaining a good build-up of heat in and around the target vessels. Recent research by Mordon et al. has suggested that delivering energy to tissue in a series of synchronized lower-fluence pulses rather that in a single shot of higher radiant flux helps achieve maximum coagulation in the deeper tissue through a progressively maintained build-up of heat [9]. The consistent effect created in and around the target vessels was obtained through the mechanism whereby coagulation in the target tissue does not occur at the first laser shot, but over the next few milliseconds. In the meantime the long interpulse interval will allow the overlying epidermis to cool down, whereas the heat remaining in and around the vessel will be steadily increased by each subsequent laser shot. Furthermore, the authors go on to suggest that the very first shot alters the optical properties of the vessel through the conversion of hemoglobin to methemoglobin, and that a train of progressively lower-powered shots would have a better effect that larger ones. No epidermal cooling was used at all and no anesthesia. It is clear that some form of good epidermal cooling, possibly pre-, intra- and post-treatment would help with the pain problem, and also prevents primary and secondary damage to the epidermis, although it must be noted that the epidermis was spared in all but the one case of blistering.

We evaluated in a preliminary study an 810 nm diode laser for the treatment of small blue and red vessels in the lower extremities up to a maximum diameter of 1 mm. When treated in combination with a new vessel compressor, the results were very promising, with an overall patient SI of over 50% at the second assessment. Compression of vessels produced satisfactory results, although this should be evaluated by comparing the treatment with non-compressed vessels to elucidate potential enhancement of this maneuver for positive results. The moderate to severe pain at the time of treatment must be controlled, and the incorporation of epidermal cooling may well address that, in addition to helping prevent primary and secondary epidermal damage, giving a better result.

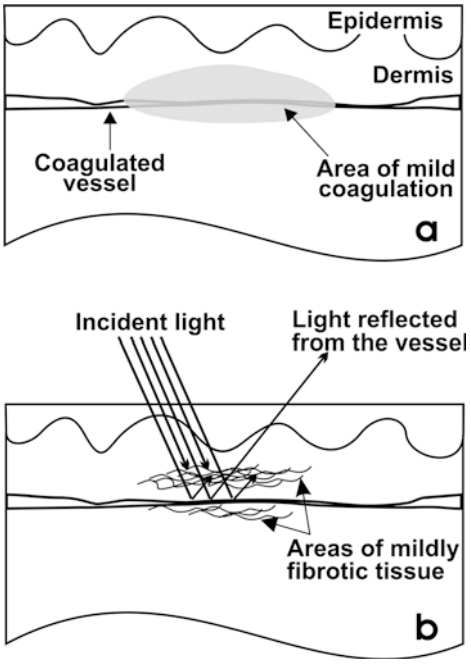


Fig. 6a, b Schematic illustrating the wound healing process after treatment of small leg veins with the 810 nm laser. **a** Region of mild coagulation formed over a coagulated vessel. **b** Formation of mildly fibrotic tissue produced by wound healing absorbs light from the treated vessel, thus helping to disguise the vessel from the macroscopic aspect

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References

1. Dover JS, Sadick NS, Goldman MP (1999) The role of lasers and light sources in the treatment of leg veins. Dermatol Surg 25:328–336
2. Fournier N, Brisot D, Mordon, S (2002) Treatment of leg telangiectasias with a 532 nm KTP laser in multipulse mode. Dermatol Surg 28:564

3. Herd RM, Dover JS, Arndt KA (1997) Basic laser principles. Dermatol Clin 15:355–372
4. Jacques SL, McAuliffe DJ(1991) The melanosome: threshold temperatures for explosive vaporization and internal absorption coefficient during pulsed laser irradiation. Photochem Photobiol 53:769–775
5. Trelles MA, Svaasand LO, Velez M, Trelles K, Fernadez R, Vekruysse W (1996) Possible mechanisms for an irregular vessel coagulation when long laser pulses are used in the treatment of port-wine stains. Dermatol Sci 13:161–166
6. Capon A, Souil E, Gauthier B, Sumian C, Bachelet M, Buys B, Polls BS, Mordon S (2001) Laser-assisted skin closure (LASC) by using a 815 nm diode laser system accelerates and improves wound healing. Lasers Surg Med 28:168–175
7. Trelles MA, Vekruysse W, Mayayao E, Velez M, Pickering JW (2002) Vessel hyalinization formation in the treatment of tuberous hemangiomas and port-wine stains. Dermatol Sci 9:70–73
8. Varma S, Lannigan SW (2000) Laser therapy of telangiectatic leg veins: clinical evaluation of the 810 nm diode laser. Clin Exp Dermatol 25:419–422
9. Mordon S, Brisot D, Fournier N (2003) Using a ''Non Uniform Pulse Sequence'' can improve selective coagulation with a Nd:YAG laser (1.06 μm) thanks to met-hemoglobin absorption: a clinical study on blue leg veins. Lasers Surg Med 32:160–170