Knee arthroscopy and venous blood flow in the lower leg

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We conducted a series of duplex ultrasound examinations to evaluate the venous blood flow in the lower leg during arthroscopic knee surgery. All knees were placed in a loosely fitted leg-holder, without a tourniquet. The flow velocity in and the diameter and area of one of the posterior tibial veins and the great saphenous vein were measured just above the ankle at 0, 100, and 180 mmHg of intraarticular pressure (IAP). All recordings were done with the lower leg dependent and the thigh both supported and unsupported by the leg-holder.

The diameter and cross-sectional area of the veins were not influenced by the IAP or by the position of the thigh in the leg-holder. There was, however, a significant increase in the venous blood flow velocity in the great saphenous vein each time the thigh was placed in the leg-holder. A simultaneous decrease in the flow velocity was seen in the posterior tibial vein and this was statistically significant at 180 mmHg IAP.

Our findings indicate an additive effect of external compression of the thigh by a leg-holder and an increased IAP, which causes a redistribution of the venous flow in the lower leg from the deep system to the superficial one.

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Arthroscopic surgery has been called "no-complication surgery" (Sherman et al. 1986) and, indeed, the rate of major complications in most studies is below 1% (DeLee 1985, Small 1986). The two major complications are infection and thromboembolic disease. Although the arthroscopy population is generally young and without the typical risk factors for developing deep vein thrombosis (DVT), this diagnosis is not uncommon. Poulsen et al. (1993) in a review article reported an incidence of thromboembolic disease after knee arthroscopy between 0.1% and 7.3%.

Stringer et al. (1989) found an incidence of DVT after arthroscopy of 4%, compared to 25% after open meniscal surgery in an otherwise similar sample of patients. This suggests that the soft tissue trauma at open surgery may be added to other risk factors, such as age of more than 30 years, a prolonged operating time and a previous history of thromboembolic disease (Kakkar et al. 1970, Sherman et al. 1986).

Temporary obstruction of the blood flow by a tourniquet has been considered a high-risk factor, but several retrospective studies (Price et al. 1980, Fahmy and Patel 1981, Sherman et al. 1986) have not confirmed this. Even in the absence of a tourniquet, disturbances of the venous flow can be created by the pressure exerted on soft tissues of the thigh by a leg-holder. Furthermore, if the knee joint is extremely distended, compression of the vessels in the popliteal fossa in contact with the surface of the operating table is possible. It is not known whether such a compression in combination with a dependent lower leg, results in venous stasis and risk of venous thrombosis.

We examined the lower leg venous flow at arthroscopy at different intraarticular pressures and compression of the posterior part of the thigh by a leg-holder.

Patients and methods

We studied 10 patients, 6 men and 4 women with a mean age of 29 (20–41) years. The diagnoses at arthroscopy were 1 patellar instability, 1 osteochondritis, 1 medial meniscus tear, 1 chronic anterior cruciate ligament (ACL) rupture, 2 chronic distorsions and 4 sequelae following arthroscopic ACL reconstruction. No capsular injuries were found at arthroscopy. No patient had varicose veins or a history of thromboembolic or cardiovascular disease.

All patients gave their informed consent to participate in the study, which was approved by the Ethics Committee of Huddinge University Hospital.

The examination was performed under general anesthesia. The mid-portion of the thigh was supported in a loosely fitted leg-holder (Arthrex München, AR 1500). The thigh circumference at the leg-holder level was recorded. With the lower leg hanging down, the

Table 1. Mean cross-sectional area (mm^2) and diameter (mm) of the great saphenous vein (GS) and one posterior tibial vein (PT) in 10 patients during knee arthroscopy with increasing IAP (0, 100, 180 mmHg) and with compression of the thigh in a leg-holder (comp). ANOVA p–values for area and diameter in relation to increasing IAP with or without thigh compression are included

Case	0		0+comp		100		100+comp		180		180+comp	
	GS	PT	GS	PT	GS	PT	GS	PT	GS	PT	GS	PT
Area mm^2												
1	8.44	8.11	8.05	9.12	6.75	5.97	9.23	10.3	6.96	–	7.23	7.83
2	12.2	8.74	12.0	9.90	12.5	6.84	10.6	6.79	11.3	10.0	11.2	6.82
3	12.6	5.92	11.6	5.66	10.2	8.10	12.0	9.09	14.7	8.21	11.4	9.29
4	7.71	6.78	8.52	5.19	10.4	8.22	8.11	8.43	7.67	9.01	7.81	9.54
5	13.0	4.17	12.2	4.70	14.0	4.43	16.7	4.89	16.2	4.66	14.5	4.15
6	16.2	14.0	16.7	12.5	18.2	13.8	17.2	16.0	16.3	16.5	18.7	18.1
7	15.7	12.1	12.9	10.1	15.6	10.1	14.8	10.0	15.9	8.61	16.6	9.66
8	15.9	8.28	15.8	8.58	18.5	10.1	19.2	9.92	27.0	9.04	19.3	10.8
9	14.2	16.0	14.7	12.9	14.1	13.5	14.3	15.3	14.6	14.1	15.1	14.6
10	7.24	9.5	8.14	9.76	5.52	11.2	6.93	11.3	5.35	6.80	–	11.0
Mean	12.3	9.37	12.1	8.84	12.6	9.23	12.9	10.2	13.6	9.66	13.6	10.2
Diameter mm												
1	–	2.90	–	3.08	–	3.42	–	3.39	–	3.27	–	3.31
2	3.97	3.39	3.90	3.52	3.83	2.48	4.06	2.45	4.36	3.40	3.68	2.66
3	3.94	2.75	3.83	2.78	4.07	2.76	4.13	2.65	3.92	2.48	3.92	2.72
4	3.10	2.75	2.86	3.00	3.60	2.64	3.21	2.80	2.90	2.94	2.82	2.44
5	3.76	1.99	3.78	2.09	3.48	2.26	3.98	2.32	4.28	2.04	3.82	2.20
6	4.03	4.13	4.38	3.33	4.50	3.81	3.98	4.06	4.28	4.58	4.51	4.66
7	4.63	3.40	4.51	3.51	4.42	2.93	4.63	2.80	4.06	2.98	4.51	3.59
8	4.85	3.27	4.06	3.20	4.17	3.11	4.78	3.18	5.01	3.78	4.74	3.27
9	4.51	4.57	4.23	4.22	4.22	4.43	4.11	4.46	3.81	4.44	4.29	4.39
10	2.71	4.18	2.41	4.10	2.02	4.21	2.33	4.03	2.47	4.17	2.63	4.11
Mean	3.94	3.33	3.77	3.28	3.81	3.21	3.91	3.21	3.90	3.41	3.88	3.34

ANOVA Area GS with comp $p = 0.1$, PT with comp $p = 0.09$
GS without comp $p = 0.4$, PT without comp $p = 1$
ANOVA Diameter GS with comp $p = 0.4$, PT with comp $p = 0.7$
GS without comp $p = 0.7$, PT without comp $p = 0.3$

arthroscope was introduced through the anterolateral portal and the position in the empty joint was confirmed by a video system. An FMS 3 arthroscopic infusion pump (FMS Scandinavia AB, Linköping, Sweden) with a high flow, 6.0 mm arthroscopy cannula, was used to distend the joint. The reliability of the pump-pressure reading with reference to the true intraarticular pressure (IAP) was tested in a series of patients not participating in the study. The IAP was stable at 5 mmHg below the pump reading in each knee.

One of the posterior tibial (PT) veins and the great saphenous (GS) vein were imaged with an ultrasound-color duplex device (Ultramark 9 HDI, Advanced Technology Laboratories, Bothell, WA, USA) having a 5–10 MHz linear array transducer. The veins were monitored 6–8 cm above the ankle joint. The position of the transducer was marked on the skin to facilitate repeated measurements in the same venous segments. Recordings of the anteroposterior venous diameter (long axis view), lumen cross-sectional area (short axis view) and the time-averaged maximal flow velocity were made after distension of the knee joint at 0, 100, and 180 mmHg. At each pressure level, recordings were made with the thigh lifted from the leg-holder and with the thigh resting in the holder. The joint was not emptied between pressure adjustments.

The recordings were videotaped and analyzed, using an integral system consisting of a MacIntosh II vx (Apple Computer, Cupertino, CA, USA), the Quick Image 24-videoframe grabber card (MASS Microsystems, Sunnyvale, CA, USA) and a Panasonic NV-FS 90 EB VCR (Matsushita Electrical Industrial, Osaka, Japan). The IMAGE software (National Institute of Health, Research Services Branch, National Institute of Mental Health, Bethesda, MD, USA) was used to trace the vessel wall echoes and measure the lumen diameter and the cross-sectional area of the veins. Calculations were performed using an application developed with 4th Dimension (ACI, Paris, France). The venous diameter (long-axis view) was calculated as the mean diameter of a 1-cm longitudinal section of the vein. The time-averaged maximal flow velocity was calculated for 3-second periods, using the software of the ultrasound duplex equipment. The B-mode values (venous lumen diameter and area) and the Doppler values (time-averaged maximal flow velocity) reported are the means of two measurements.

The coefficients of variation for duplicate measurements were 2.5% (PT) and 3.9% (GS) for diameter measurements, 12% (PT) and 5.6% (GS) for area measurements and 6.8% (PT) and 5.7% (GS) for flow velocity measurements.

The total ultrasound examination lasted approx 30 min, after which the arthroscopic surgery was performed.

Statistics

Changes in the venous flow velocity and the cross-sectional area and diameter of vessels were evaluated by the Student's paired t-test and analysis of variance (ANOVA). The distributionally skewed values of changes in the PT flow velocity with increasing IAP were evaluated by Wilcoxon's test and Friedman's test. The correlations between the thigh circumference and the pressure level and flow velocity in the GS vein were evaluated by simple regression analysis and in the PT vein by Spearman's test.

Statistical significance was defined as $p < 0.05$.

Results

The diameters and cross-sectional areas of the GS and PT veins were not affected by an increased IAP with or without thigh compression (Table 1). At each pressure level, positioning of the thigh in the leg-holder increased flow velocity in the GS vein (Table 2). The PT vein flow velocity tended to decrease during positioning of the thigh in the leg-holder, the decrease being statistically significant at 180 mmHg IAP (Table 2).

Raising of the IAP increased the flow velocity in the GS vein when the thigh was resting in the leg-holder, but not when the thigh was lifted from the leg-holder (Table 2). Raising of the IAP tended to reduce flow velocity in the PT vein when the thigh was resting in the leg-holder (Table 2).

Thigh circumference did not correlate with the flow velocity at any pressure level in either the GS or the PT vein when the leg was positioned in the-leg holder (GS r = –0.55/–0.40/–0.52, n.s; PT r = 0.07/0.04/0.17, n.s) (Table 2).

7 patients had no measurable flow in the PT vein on 3 occasions with the thigh lifted from the leg-holder and on 14 occasions with the thigh resting in the leg-holder.

Table 2. Blood flow velocity (cm/sec) in the great saphenous (GS) and one posterior tibial vein (PT) in 10 patients during knee arthroscopy with increasing IAP (0, 100, 180 mmHg) and with compression of the thigh in a leg-holder (c). Thigh circumference at leg-holder level (cm). Columns compared with ANOVA and Friedman's test are indicated with *

Case	0	0+c	100	100+c	180	180+c	Thigh
GS flow velocity							
1	13	25	18	24	17	26	50
2	22	34	26	43	23	42	48
3	15	23	14	25	11	22	54
4	20	21	13	23	17	21	60
5	7.6	14	12	19	9.8	15	56
6	12	15	11	22	10	21	55
7	17	21	20	25	16	28	58
8	31	29	26	30	22	35	53
9	14	21	17	23	14	22	54
10	6.8	22	9	19	8.6	24	48
Mean	16	22	16	25	15	26	
p-values							
t-test	0.003		0.0001		0.0001		
ANOVA	*		*		*		0.48
ANOVA		*		*		*	0.02
PT flow velocity							
1	12	0	9.0	0	0	0	
2	12	4.2	5.9	2.1	11	0.6	
3	6.1	1.5	5.5	0	4.3	0	
4	13	22	12	18	12	13	
5	5.6	0	7.1	1.6	9.5	0.8	
6	7.5	5.3	5.9	0	5.9	0	
7	2.9	0.1	2.3	0	4.4	0	
8	0	0	0	0	1.9	0	
9	8.7	1.6	5.9	0.8	6.0	0	
10	5.4	8.6	6.1	7.8	6.1	10	
Median	6.8	1.5	5.9	0.4	5.9	0	
p-values							
Wilcoxon	0.17		0.05		0.03		
Friedman	*		*		*		0.22
Friedman		*		*		*	0.07

Discussion

Non-invasive duplex ultrasonography is considered to yield accurate and reproducible determinations of venous dimensions and flow velocity waveforms (Zwiebel 1992). The ultrasonic technique has been used to study venous hemodynamics during surgery (Comerota et al. 1989, Warwick et al. 1994). In a study of the pelvic venous circulation during transurethral resection of the prostate (Nilsson et al. 1996), substantial iliac vein obstruction due to bladder distension was detected using an experimental model similar to ours.

The major venous return flow from the lower leg comes from the superficial venous system via perforating veins into the deep venous system. The deep calf veins are emptied by the muscle pump into the popliteal and femoral veins (Almén and Nylander 1962). Passive plantar flexion results in only a slight emptying of the calf veins (Nicolaides et al. 1971), indicating that manipulation of the leg during surgery does not significantly enhance the venous return flow. The frequent changes in leg position usually made during arthroscopy should, however, counteract the lower leg venous stasis induced in the unconscious patient.

In our study, positioning of the thigh in the leg-holder obviously affected the venous hemodynamics in the lower leg. Since the vessel diameters and areas remained unchanged, the changes in flow velocity in the two veins studied must have been caused by a decreased flow in the PT vein and a compensatory increase of flow in the GS vein. Increasing the IAP caused small changes in venous flow while the thigh was resting in the leg-holder. The importance of the IAP level for venous flow is unclear, despite the significant effect on flow velocity at 180 mmHg IAP. This could be an additive effect to the external compression on the thigh, but it is not possible to evaluate the precise physiological mechanism responsible using our data.

The size of the tourniquet, the subcutaneous fat layer and the muscles, as well as the contact area of the leg-holder, determine the extramural pressure on the thigh veins during arthroscopy. A mid-thigh 2.5 cm wide tourniquet with inflation pressure of 180 mmHg has been shown not to disturb the deep venous flow (Nicolaides and Yao 1980). As the tourniquet was applied on a standing individual, the tissue pressure must have been evenly distributed in the thigh, which may explain why deeply located vessels were not influenced by the high pressure. The leg-holder used in our study was 9 cm wide with the contact area mainly with the posterior part of the thigh but without contact with the GS vein. The force thus created by the weight of the leg is obviously large enough to affect the superficial femoral vein even though this vessel is located anterior to the hamstring muscle bellies at the leg-holder level.

A large thigh volume does not seem to protect the deep vessels from the increased pressure caused by the leg-holder and it is questionable whether the thigh can be padded to such an extent that vessel function is not disturbed.

The etiology of DVT is represented classically as an effect of Virchow's triad: reduced blood flow, endothelial damage and blood hypercoagulability (Virchow 1856). A reduced blood flow is obviously readily provoked during arthroscopy, as 7 of 10 patients in our study showed no flow in at least one of the veins in the deep system during some part of the examination. Whether short-interval flow disturbances during knee arthroscopy are of importance for the development of postoperative DVT is not clear, but an unnecessarily long static position of the thigh in a leg-holder should probably be avoided.

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