ORIGINAL ARTICLE

Conventional Versus Neutral Positioning in Central Neurological Disease

A Multicenter Randomized Controlled Trial

Heidrun Pickenbrock, Vera U. Ludwig, Antonia Zapf, Dirk Dressler

SUMMARY

Background: Severe immobility due to lesions of the brain necessitates therapeutic positioning over the long term. There is little scientific evidence concerning the efficacy of different positioning methods. This clinical trial compares the effects of conventional positioning (CON) with those of positioning in neutral (LiN).

Methods: A prospective, multicenter, investigator-blinded, randomized, controlled trial was performed on a total of 218 non-ambulatory patients (underlying disease: stroke, 141 patients; hypoxic brain damage, 28; traumatic brain injury, 20; other, 29). The subjects were randomly assigned to either LiN (105 patients) or CON (113 patients) and stratified within each of these two positioning concepts to five different positions. They remained in the assigned positions for two hours. The primary endpoint was change in the passive range of motion (PROM) of the hip joints. Secondary endpoints were change in the PROM of the shoulder joints and patient comfort.

Results: Patients in the LiN group had a significantly better PROM of the hips after positioning than those in the CON group (difference, 12.84°; $p < 0.001$; 95% confidence interval [CI], 5.72°–19.96°). The same was true for PROM of shoulder flexion (11.85°; $p < 0.001$; 95% CI, 4.50°–19.19°) and external rotation (7.08°; $p < 0.001$; 95% CI, 2.70°–11.47°). 81% of patients in the LiN group reported their comfort level as good, compared to only 38% in the CON group ($p < 0.001$).

Conclusion: Positioning severely immobilized patients in LiN for two hours improved passive hip and shoulder mobility and patient comfort compared to conventional positioning. Further studies are needed to determine whether prolonged LiN positioning might improve rehabilitation and quality of life, prevent pressure sores, or ease nursing care.

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Various neurologic conditions produce large numbers of patients with severe immobility. In Germany, new cases of stroke alone account for about 45 000 severely immobilized patients each year (1). These patients need to be regularly positioned and repositioned over a long period. This is part of routine nursing care in acute wards and during rehabilitation. Effective patient positioning reduces patient discomfort and prevents secondary complications including pressure sores and pneumonia (2, 3). Prone position and backrest elevation have positive effects in patients with lung problems, but can lead to pressure ulcers (4). Compared to lying flat, upright positioning can lead to a wide range of individual reactions (5). This may be the reason why there is still no agreement among nurses and therapists about the best positions for stroke patients (6). Equally unclear is how often the position should be changed in order to prevent pressure ulcers (7).

During the rehabilitation period, effective patient positioning can enhance functional recovery, prevent contractures, and normalize muscle tone (8). Conversely, suboptimal positioning can reduce passive range of motion (PROM). However, the efficacy of various positions has rarely been studied before now, and to date no systematic comparison has been carried out of the efficacy of various positioning concepts.

Conventional positioning (CON) is performed by changing the patient's position every 2–3 hours between different supine, prone or lateral positions by using positioning material placed under defined body parts. The positioning is done with little consideration of the position of the body segments in relation to each other (9). By contrast, in positioning in neutral (*Lagerung in Neutralstellung*, LiN), an important part is played by the alignment of the body parts. Attention is focused on ensuring that muscle groups are neither shortened nor lengthened, and that stability is provided to paretic body parts (Pickenbrock H, et al.: Therapeutic effects of positioning patients with CNS-lesion—RCT. 2014; WCNR: ref. no. 95, poster no. PP-525 http://wcnr2014.org/abstract_results-46.html [last accessed 8 July 2014]; further comparative details are shown in *Figure 1*) (10). LiN requires more positioning material, such as bedding and pillows, than CON. In combination with special stabilizing

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Figure 1: Example of conventional positioning (CON) and positioning in neutral (LiN) for a patient lying on the right side. The figure shows a typical 90° side lying position (a: CON; b: LiN). In both approaches the patient is lying entirely on one side, the upper leg is flexed, the lower leg may be flexed or extended.

- a) In CON, the stabilizing materials are placed at certain defined sites (e.g., at the back, under the leg). The body adapts to the mattress, and the effect this has on the alignment of the body parts is not taken into account. Hollow spaces can occur or are required (22). Support material is intended to be used quite sparingly. Positioning a patient conventionally is simple. In the position shown, a rolled duvet and a rolled towel are placed behind the trunk. A small pillow supports the abdomen. The cervical spine is unsupported and the head is slightly raised. The torso is laterally flexed. The shoulder girdle malaligns to the elevation and is compressed towards the trunk. The upper leg is adducted. Points of pressure occur at the ears, the lower shoulder, the ribs, and the greater trochanter. These areas are at risk of pressure ulcers.
- b) In the LiN approach, the focus is on the alignment of the body segments. Overstretching and shortening of muscles are avoided. The joints are positioned as neutrally as possible. All parts of the body are supported against the influence of gravity. Paretic body segments are stabilized using special techniques. Every hollow space should be filled. A sufficient number of blankets and pillows is needed to follow these principles. This makes LiN slightly more demanding than CON. Applying these principles in the position shown requires a folded duvet to be placed under the trunk while using its ends to stabilize the trunk behind and in front. The position of the body segments relative to each other is considered while in particular the upper leg, the cervical spine, and the head are completely supported. The pressure of the body is distributed over the whole bed, so the risk of pressure ulcers is low.

techniques, the materials are thought to allow patients to relax. At the same time, they offer a much broader base of support than CON by distributing the patient's body weight more evenly. The resulting relief of load on heels, ischium, and sacrum reduces the risk of pressure ulcers at these places (11).

The aim of the present study was to compare the efficacy of LiN and CON respectively in severely immobile patients. Since contractures have a negative effect on mobility and the outcome of rehabilitation, and since pain due to reduced PROM makes nursing more

difficult, we investigated the effect of positioning on PROM (12–14). We were also interested in patients' sense of well-being, and therefore also assessed the comfort provided by the two different positioning concepts. We hypothesized that LiN would have stronger effects on both PROM and comfort.

Methods

This multicenter, prospective, randomized, controlled study was carried out in 22 centers in Germany and Austria (eTable 1). In each center, a trained therapist or

nurse was responsible for ensuring that the study protocol (*eSupplement* under “Methods”) was followed. The investigators involved in the study were members of the association LiN-ARGE e.V., a not-for-profit organization, the aim of which is to disseminate knowledge of the LiN approach.

The Research Ethics Committee of the Westfalen-Lippe Medical Association and the Medical Faculty of the Westfälische Wilhelms University Münster approved the study. The study was registered with the German Clinical Trials Register (15).

Sample size calculation was based on a pilot study of 12 acute stroke patients (mean standard deviation for hip flexion: $7.5^\circ \pm 15.7^\circ$ for 6 LiN patients and $3.0^\circ \pm 4.5^\circ$ for 6 CON patients).

For a two-sided type one error of 5% and a power of 80%, 106 patients per group were calculated as the required sample size using the *t* test with Satterthwaite approximation.

Prior to the study, a Microsoft Excel file was created for the purpose of randomization. The first column listed the various conditions (five positions each in LiN and CON: supine, 30° side lying right or left, 90° side lying right or left). Participants' numbers were listed in the second column. In the third column, a random number was produced for each participant using the function =Rand(). Participant numbers were then sorted according to the randomly generated numbers and each was assigned to one of the conditions (16).

The study was carried out without external funding. All authors vouch for the accuracy of data acquisition, processing and analysis, and assure compliance with the study protocol.

Patients

The patients were recruited from stroke units, intensive care units, early rehabilitation centers, geriatric rehabilitation centers, secondary rehabilitation centers and nursing homes. Inclusion criteria were a minimum age of 18 years and central paresis with severe disability (non-ambulatory patients: 4 and 5 on the Modified Rankin Scale [17]).

Exclusion criteria were fixed contractures, considerable agitation, and the need of backrest elevation. Patients were included in the study only if they or their legal custodians had provided written informed consent before start of the study. A physician ascertained the eligibility of enrolled patients.

Endpoints

The primary endpoint of the study was change in the passive range of motion (PROM) of the hip joints (before–after positioning). Secondary endpoints were change in shoulder flexion and external rotation PROM and patient comfort. PROM was measured using a standard goniometer before the position (LiN or CON) was started and after 2 hours' lying in the respective position (for details, see *eSupplement*, “Methods,” and *eFigures 1–3*). Patient comfort was recorded after the intervention from those patients who were able to com-

municate, using a three-point scale (“good”, “fair”, and “bad”, each visualized by an emoticon).

Procedure

At first the patients lay on their back with only a pillow under their head; that is, they were not positioned according to either of the approaches. The investigator, who had been trained to perform a standardized procedure prior to the study and was not involved in the daily routine, measured the PROM and then left the room. Next, a therapist or nurse positioned the patient in the allocated LiN or CON position. After 2 hours, the patient was returned by this person to the starting position. The investigator then measured the PROM and recorded the comfort score. This procedure ensured that the investigator was blinded to the patient positioning.

Intervention

In the present study, the patient positions used were those most commonly in use in Western Europe: supine, 30° side lying right or left and 90° side lying right or left. To ensure standardized intervention, participating centers were provided with worksheets describing each of the procedures. These worksheets can be obtained on request from the first author.

For LiN, the original worksheets of the LiN approach were used. For CON, the procedure was derived from the literature (18–21). In order not to exert any additional effects on the PROM, all measures performed during positioning had to be carried out passively and large movements of the extremities had to be avoided. After being positioned, patients were asked to stay in this position for 2 hours, but were also told that they were permitted to change their position at any time.

Statistics

SAS 9.3 software was used for the statistical analysis. Category variables were compared between groups using either the χ^2 test or, in the case of cell frequencies <5 , using Fisher's exact test. For metric variables, the two treatment groups were compared assuming a normal distribution and equal variance using the *t* test for two independent samples. When normal distribution and unequal variance were assumed, that *t* test was used with Satterthwaite approximation. If normal distribution could not be assumed, the Mann–Whitney *U* test was used.

The primary analysis was performed for the intention-to-treat population. In this case, this means that patients who spontaneously repositioned themselves were analyzed as randomized. The two-sided alpha error was set at 5%.

For the primary analysis, ANCOVA (analysis of covariance) was used with change (before–after positioning) of PROM of the hips ($\Delta_{\text{PROM hips}}$) as dependent variable (mean of the left and the right side). The independent variables were type of positioning (2 conditions: LiN, CON) and, because of stratified randomization, the position (5 conditions: supine position,

Enrollment and randomization of patients
(CONSORT [22]).
LiN: positioning in neutral; CON, conventional positioning

FIGURE 2

30° side lying right or left, and 90° side lying right or left). Baseline PROM values were included as covariates. Interaction between independent variables was also included in the model. For sensitivity analyses, a complete case analysis and nonparametric ANCOVA were performed.

As a secondary analysis, shoulder PROM values were compared in the same procedure as described above. To compare comfort between the groups, the χ^2 test was used. All results are presented in accordance with the CONSORT statement (22).

Results

Patients

From October 2010 to October 2012, 454 patients were screened for eligibility. A total of 218 patients were randomized and assigned to the intended interventions (Figure 2). Patient recruitment ceased when the calculated group size was reached. The Table shows the baseline values in the study population, including the incidence of the various causes of the neurological disorders. Further details are given in eTable 2. In terms of demographic variables, there were no relevant differences between the LiN and the CON group. Slight differences ($p < 0.2$) were seen only in relation to age and duration of illness ($< / > 6$ months). If these parameters were included in the model in a sensitivity

analysis, the results were robust (further details in eSupplement under “Results”).

Intervention

The patients were equally distributed over the five positions ($p = 0.92$; details in eTable 3). In the LiN group, six patients (5.7%) had left their position; in the CON group, nine (7.9%). One patient in the LiN group had to be propped up due to orthopnea. In one patient in the CON group, the data after the positioning were missing because of intervening digestive problems. For this patient, the baseline observations were carried forward.

Primary endpoint

The ANCOVA showed a statistically significant improvement in hip PROM after 2 hours in position in the LiN group (change from baseline: $\Delta_{\text{PROM hips}}$) compared to the CON group ($\Delta_{\text{PROM hips [LiN]}} - \Delta_{\text{PROM hips [CON]}} = 12.84^\circ$, $p < 0.001$; 95% confidence interval [95% CI]: 5.72° to 19.96°). Mean values and 95% CI for the various subgroups are shown in Figure 3 and eTable 4.” The positions (supine, 30° side lying right or left, 90° side lying right or left) had no relevant effect ($p = 0.119$). Likewise, no relevant interaction was shown between the two approaches and the positions ($p = 0.374$). The effect of the baseline measurements,

TABLE

Demographic characteristics and baseline values of clinical characteristics of study patients

	LiN group	CON group	p value
Patients, n (%)	105 (48%)	113 (52%)	
Male n (%)	64 (62%)	73 (65%)	0.68
Age (years)	69.05 ± 15.84	65.27 ± 16.45	0.09
Diagnosis, n (%)			
– Stroke	71 (68%)	70 (62%)	0.27
– Hypoxic brain injury	12 (11%)	16 (14%)	
– Craniocerebral trauma	12 (11%)	8 (7%)	
– Other	10 (10%)	19 (17%)	
Duration of illness <6 months, n (%)	88 (84%)	84 (74%)	0.10
Paresis, n (%)			
– Hemiplegia	59 (56%)	54 (48%)	0.46
– Tetraplegia	41 (39%)	53 (47%)	
– Other	5 (5%)	6 (5%)	
Baseline values			
– Hips, flexion (°)*	73.31 ± 17.49	73.16 ± 20.31	0.96
– Shoulders, flexion (°)*	58.76 ± 39.35	64.56 ± 38.74	0.27
– Shoulders, external rotation (°)*	16.60 ± 17.29	15.57 ± 15.27	0.64
More affected side, n (%)			
– Right	36 (34%)	43 (38%)	0.66
– Left	39 (37%)	38 (34%)	
– No difference	23 (22%)	28 (25%)	
– Not specified	7 (7%)	4 (4%)	
Patients according to center type, n (%)			
– Acute ward	20 (20%)	15 (14%)	0.33
– Intensive care unit	17 (17%)	10 (9%)	
– Early rehabilitation	51 (50%)	64 (58%)	
– Geriatric rehabilitation	7 (7%)	9 (8%)	
– Nursing home	2 (2%)	3 (3%)	
– Other	8 (5%)	12 (9%)	

*Mean of two sides ± standard deviation.

LiN: positioning in neutral; CON: conventional positioning

on the other hand, was significant. Lower baseline values predicted stronger increases in PROM (estimate = −0.11, 95% CI: −0.20° to −0.02°; $p = 0.013$).

Sensitivity analysis demonstrated the robustness of the results ($p \leq 0.001$ in all cases; $\Delta_{\text{PROM hips}} [\text{LiN}] - \Delta_{\text{PROM hips}} [\text{CON}]$ between 7.31° and 13.41°).

Secondary endpoints

The effects on shoulder mobility were found to be similar to those on hip mobility. For shoulder flexion, the difference between LiN and CON $\Delta_{\text{PROM shoulders}} [\text{LiN}] - \Delta_{\text{PROM shoulders}} [\text{CON}] = 11.85^\circ$ (95% CI: 4.50° to 19.19°), and for external rotation of the shoulders it was

7.08° (95% CI: 2.70° to 11.47°). Further details are given in *eTable 5*.

Seventy-nine patients were unable to communicate, and an answer from one patient was missing. Hence, $n = 138$ patients (LiN: $n = 69$, CON: $n = 69$) were able to answer the question about the comfort of the applied position. Comfort was assessed as significantly better for the LiN approach than for the CON approach ($p < 0.001$; *Figure 4*).

Additional analyses relating to the effects of positioning on the patient's more affected versus less affected body side are given in the *eSupplement* under "Additional analyses" and in *eTables 6 and 7*.

FIGURE 3

Primary endpoint: change in passive range of motion (PROM) of hip joints, in degrees

LiN: positioning in neutral; CON: conventional positioning

FIGURE 4

Secondary endpoint: Patient comfort in LiN and CON (χ^2 -test shows a significant difference [$p < 0.001$]).

LiN: positioning in neutral; CON: conventional positioning

Discussion

Consistently carried out positioning and repositioning of patients with acquired brain damage and severe immobility is of great importance. These patients need effective postural management to enhance and reinforce recovery of function (23). Currently recommended forms of positioning following conventional principles (CON) are rarely used in practice (24–26). There is a lack of studies of the influence of positioning on functional recovery.

The present study shows that positioning patients in a neutral position (LiN) is easily applied within daily clinical routine, can increase the passive mobility of hip and shoulder joints, and is experienced by the patients as noticeably more comfortable than a CON. The improved comfort especially means that LiN should be considered not just for patients with neurological impairment, but also for immobilized patients in intensive care or in the geriatric unit. The principles of LiN (alignment, support and stabilization of the body parts) can be applied not just in the positions studied here—lying on the back or sides—but also in other positions such as lying prone, 135° tilted, or sitting up in bed or on a chair.

Since manual goniometer measurements have recently been criticized for problematic inter-rater reliability, we requested pre/post measurements by the same assessor. To compensate for possible inaccuracies of manual goniometer measurements, we required relevance thresholds of 8° for hip flexion, 7° for shoulder flexion, and 11° for external shoulder rotation (27, 28). All our therapeutic effects except for shoulder rotation were well above this threshold.

The intervention time was 2 hours, the shortest time recommended for preventing any form of pressure ulcer (2, 3). It may be assumed that longer intervention times would result in even stronger effects.

We ruled out the possibility that any conversations between the patients and the assessors might explain the results obtained. The analysis carried out on only those patients who were unable to communicate showed a similar effect to the primary analysis ($n = 79$; $\Delta_{\text{PROM hips}} [\text{LiN}] - \Delta_{\text{PROM hips}} [\text{CON}] = 13.14$, $p = 0.03$ [*eSupplement*, “Additional analyses”]).

Previous clinical studies of patient positioning aimed at improving shoulder mobility in stroke patients have been unable to show any improvement in this parameter (29). This may be due to a variety of methodological differences to the present study. In the first place, the earlier studies positioned only the hemiplegic arm, not the whole body. Secondly, the arms were placed in a stretched position in order to counteract muscular shortening. We, by contrast, placed all the segments of the body including the arms in such a way that muscles were neither stretched nor shortened.

Various factors may contribute to the beneficial effects of LiN on passive mobility and patient comfort. First, the large support area and the stabilization applied allow the patient relax, and hence both perceived comfort and PROM improve. On the neurophysiological level, it is likely that, because overstretching and shortening of the musculature are avoided, changes take place in tactile, proprioceptive, and nociceptive afferences are altered, which may have an inhibitory effect, via spinal reflex mechanisms, on muscular hyperactivity.

Summary

The intervention time was limited to 2 hours. Due to this, a number of questions remain unanswered:

- Can LiN reduce the risk of pressure ulcers developing?
- What are the long-term effects of this positioning method?
- Could, for example, using LiN for several weeks have an effect on patients' levels of activity, participation, or quality of life?

We hypothesize that LiN could have a positive influence on these parameters if the positioning is carried out over many hours of the day and for as long as the patient is unable to move independently. Further studies are needed to answer these questions.

Conflict of interest statement

H. Pickenbrock developed the LiN approach and is a member of LiN-Arge e.V., a not-for-profit organization that promotes the LiN approach.

V. U. Ludwig is related to H. Pickenbrock, the first author.

A. Zapf received a fee for the statistical analysis.

D. Dressler declares that no conflict of interest exists.

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KEY MESSAGES

- Severe immobility requires regular patient positioning.
- Positioning in neutral (LiN) is a new approach to patient positioning.
- The effects of two positioning approaches were investigated for an observation period of 2 hours.
- LiN had relevantly positive effects on the passive range of movement of the hip and shoulder joints compared with conventional positioning (CON).
- LiN was experienced as noticeably more comfortable than conventional positioning.

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For eReferences please refer to:
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eSupplement, eTables, eFigures:
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ORIGINAL ARTICLE—eSUPPLEMENT

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Methods

Study protocol

LiN-Arge members were trained for the study during the biannual meetings of the association in September

2010, February and October 2011, and March 2012. The first patient was enrolled in the study on 5 October 2010 and the last on 20 October 2012. The study was closed when the calculated sample size was reached.

eTABLE 1

Participating centers

Place	Name	Type of care	Number of patients		
			CON	LiN	Total
Germany					
Bad Neustadt/Saale	Neurologische Klinik	Early rehabilitation	15	5	20
Bad Oeynhausen	Johanniter Ordenshäuser	Early rehabilitation	6	9	15
Bonn	Rheinische Kliniken	Intensive care	4	9	13
Bremen	Klinikum Bremen-Ost	Early rehabilitation	16	11	27
Burgau	Therapiezentrum	Early rehabilitation	6	4	10
Gelsenkirchen	KKEL-St. Hedwig Hospital	Secondary rehabilitation care	3	2	5
Gladbeck	KKEL-St. Barbara Hospital	Acute care	0	2	2
Gummersbach	Kreiskrankenhaus	Acute care	5	4	9
Hildesheim	St.-Bernward Krankenhaus	Acute care	0	5	5
Jockgrimm	Lina-Sommer AWO-Seniorenhaus	Nursing home	3	2	5
Kipfenberg	Klinik Kipfenberg	Intensive care	4	9	13
Leipzig	St. Georg Krankenhaus	Secondary rehabilitation care	7	3	10
Lingen	St. Bonifatius Hospital	Geriatric rehabilitation	4	2	6
Murnau	BG-Klinik	Intensive care	2	2	4
Neresheim	SRH-Krankenhaus	Early rehabilitation	22	18	40
Recklinghausen	Prosper-Krankenhaus	Acute care	2	3	5
Saarbrücken	Universitätsklinikum	Stroke unit	2	2	4
St. Wendel	Marienkrankenhaus	Acute care	4	1	5
Telgte	Klinik Maria Frieden	Geriatric rehabilitation	2	3	5
Siegburg	St. Josef Hospital	Stroke unit	1	4	5
Troisdorf	Private addresses	Care at home	2	3	5
Austria					
Linz	SWH Karl Borromäus	Department of long-term ventilation, weaning	3	2	5

CON: conventional positioning; LiN: positioning in neutral

Before the study started

- Investigators were trained (1 hour) in how the study would run and the procedure for measuring passive range of motion (PROM) (see further details below).
- Study documentation was issued, including worksheets (obtainable from the first author) and the sealed envelopes containing pre-generated randomized assignments of patients' positions.

In the study center (eTable 1)

- Study was explained to the management of the center and permission received to carry it out (five patients planned per center where each participating LiN-Arge member worked).
- Start date fixed for the study in that center.
- Informed consent forms printed on center's letter-head paper in accordance with ethics committee requirements.

Patient enrollment

- All patients eligible for inclusion at the start date of the study were registered: adult patients unable to walk (Modified Rankin Scale 4 or 5) with central paresis. The presence of any exclusion criteria (such as fixed contractures, considerable agitation, problems with lying flat) were documented.
- Recruitment forms were presented to the physician in charge
 - if more than five patients fulfilled the study's inclusion criteria, and if the number of patients exceeded the center's capacity, patients were randomly selected for inclusion.
 - If fewer than five patients were present on the study start date, each subsequent patient would be tested for eligibility and recruited as appropriate.
- Patients or their custodians provided written informed consent.

Planning the intervention

- The wards involved were informed about the project.
- The wards were consulted in planning the timing of the positioning.

Intervention

Ensure that the investigator cannot anticipate which positioning approach the patient has been lying in.

First measurement

- The patient is brought passively into a supine position and provided with only a head pillow of adequate height.
- The PROM is measured (eFigures 1–3) and the measurement(s) noted in the patient record.

eFigure 1: Measuring flexion in the hip

a) The thigh together with all its structures is brought into the neutral-zero starting position

b) Starting the flexion movement

c) The knee should be flexed to 90°. The measurement is taken on the first attempt, as soon as

- the slightest resistance occurs
- the extremity deviates out of the plane of movement
- pain occurs

d) For the measurement

- one lever of the goniometer is parallel to the treatment table or bed
- the other lever is on the middle of the femur
- the axis of the goniometer is on the greater trochanter

eFigure 2: Measuring flexion in the shoulder

a) At the start of the movement, the humerus is in the neutral-zero position and the elbow is 90° flexed

b) End of the movement (example)

- The measurement is taken on the first attempt, as soon as
- the slightest resistance occurs
- the extremity deviates out of the plane of movement
- pain occurs

c) For the measurement

- the lever of the goniometer is parallel to the treatment table or bed
- the other lever is on the middle of the humerus
- the axis of the goniometer is on the middle of the humeral head

Procedure when positioning the patient (nurse or therapist)

- The nurse or therapist is briefly instructed in how to use the worksheets and given the envelope containing the information about the assigned position and positioning approach. If the position is not possible (e.g., left side lying for a patient with heart problems), another position within the assigned positioning approach is chosen.
- The patient is passively positioned into the allocated position, avoiding large movements of the arms and legs.
- The patient is asked to remain in that position if possible, but at the same time given permission to change position if necessary.

eFigure 3: Measuring external rotation of the shoulder

a) At the start of the movement, the humerus is in the neutral-zero position and the elbow 90° is flexed

b) For the measurement

- one lever of the goniometer is vertical
- the other lever is on the middle of the forearm
- the axis of the goniometer is on the middle of the olecranon

eTABLE 2

Distribution of diseases

Diagnosis	CON, n (%)	LiN, n (%)	Total, n (%)
Ischemic stroke	31 (27%)	33 (31%)	64 (29%)
Hemorrhagic stroke	33 (29%)	30 (29%)	63 (29%)
Stroke (no further details)	6 (5%)	8 (8%)	14 (6%)
Hypoxic brain injury	16 (14%)	12 (12%)	28 (13%)
Head trauma	8 (7%)	12 (12%)	20 (9%)
Dementia	3 (3%)	3 (3%)	6 (3%)
Multiple sclerosis	2 (2%)	2 (2%)	4 (2%)
Infantile cerebral palsy	3 (3%)	1 (1%)	4 (2%)
Encephalitis	4 (4%)	0 (0%)	4 (2%)
Patient in vegetative state	2 (2%)	0 (0%)	2 (1%)
Subarachnoid hemorrhage	1 (1%)	1 (1%)	2 (1%)
Paraplegia	0 (0%)	2 (2%)	2 (1%)
Brain tumor	1 (1%)	1 (1%)	2 (1%)
Metabolic encephalopathy	1 (1%)	0 (0%)	1 (1%)
Meningitis	1 (1%)	0 (0%)	1 (1%)
Locked-in syndrome	1 (1%)	0 (0%)	1 (1%)
Total	113	105	218

CON: conventional positioning; LiN: positioning in neutral

eTABLE 3

Distribution of positions, including the number of incomplete interventions

	90° Left side lying	30° Left side lying	Supine	30° Right side lying	90° Right side lying
LiN, n (%)	21 (20.0%)	23 (21.9%)	22 (21.0%)	21 (20.0%)	18 (17.1%)
SCP, n	1	4*			1
CON, n (%)	22 (19.5%)	23 (20.4%)	23 (20.4%)	20 (17.7%)	25 (22.1%)
SCP, n	3	1	1	3	1

χ^2 test: $p = 0.92$; *One patient had to be propped up due to orthopnea.

SCP: spontaneous change in position; CON: conventional positioning; LiN: positioning in neutral

After two hours

- The patient is passively moved into a supine position (avoiding large movements of arms and legs).
- Feedback as to whether patient maintained the position or changed it.

Second measurement

- PROM
- Comfort: rating by communicative patients of how comfortable they felt:
 - Patient asked whether the position felt “good,” “fair,” or “bad.”
 - Patient asked to tap on an emoticon.
- Results noted in the patient record.

Measuring passive range of motion

Passive range of motion (PROM) was measured based on the neutral-zero method. This means that the shoulders or hips are first brought into their neutral position. For hip flexion, the knee was brought into a 90° position during the measurement. For flexion and external rotation of the shoulders, the elbow was brought into 90° flexion before the measurement.

Each extremity was moved only once. The measurement was taken during the first passive movement as soon as the investigator felt the slightest resistance, or

eTABLE 4

PROM values of hips and shoulders at baseline, separately for right and left (mean $\pm$ standard deviation)

Joint	LiN	CON
Hip flexion, right	71.95° $\pm$ 19.61°	72.79° $\pm$ 21.33°
Hip flexion, left	74.67° $\pm$ 18.32°	73.54° $\pm$ 21.40°
Shoulder flexion, right	57.18° $\pm$ 41.50°	63.72° $\pm$ 40.68°
Shoulder flexion, left	60.36° $\pm$ 41.37°	65.84° $\pm$ 40.83°
Shoulder external rotation, right	16.81° $\pm$ 18.43°	16.43° $\pm$ 18.68°
Shoulder external rotation, left	15.90° $\pm$ 19.63°	15.04° $\pm$ 16.97°

PROM: passive range of motion; CON: conventional positioning; LiN: positioning in neutral

the extremity deviated out of the plane of movement, or pain occurred during this one attempt.

Investigators used a standard double-armed 360° goniometer made of clear plastic. One lever was held horizontally (or, for external rotation, vertically), the other laid on the middle of the extremity. The axes were formed respectively by the greater trochanter and the middle of the humeral head (*eFigures 1–3*).

The values were recorded in 5° steps, each measurement being rounded up or down to the nearest 5° level.

eTABLE 5

Descriptive measures of change in PROM (before–after positioning) in the different positions

Position	CON	LiN	Hip flexion		Shoulder flexion		Shoulder external rotation	
	n	n	CON	LiN	CON	LiN	CON	LiN
	Mean $\pm$ SD		Mean $\pm$ SD		Mean $\pm$ SD		Mean $\pm$ SD	
90° left side lying	22	21	1.48 $\pm$ 7.39	10.24 $\pm$ 11.37	0.34 $\pm$ 10.81	6.02 $\pm$ 9.28	0.48 $\pm$ 6.50	5.95 $\pm$ 7.05
30° left side lying	23	22	1.52 $\pm$ 13.14	5.34 $\pm$ 9.04	3.37 $\pm$ 15.44	11.00 $\pm$ 11.90	1.91 $\pm$ 7.45	5.11 $\pm$ 8.00
Supine	23	22	–6.20 $\pm$ 23.55	5.91 $\pm$ 5.59	–1.74 $\pm$ 9.15	10.68 $\pm$ 9.73	–1.15 $\pm$ 6.10	6.36 $\pm$ 9.41
30° right side lying	20	22	0.88 $\pm$ 12.52	8.64 $\pm$ 8.89	–2.63 $\pm$ 11.25	5.11 $\pm$ 17.72	0.13 $\pm$ 7.59	3.75 $\pm$ 7.19
90° right side lying	25	18	2.6 $\pm$ 11.24	6.94 $\pm$ 8.85	0.70 $\pm$ 11.01	14.17 $\pm$ 17.02	4.66 $\pm$ 10.53	5.42 $\pm$ 5.37

CON: conventional positioning; LiN: positioning in neutral; PROM: passive range of motion

eTABLE 6

Cross reference table for more-affected side and side lain on in patients with hemiplegia

More-affected side	Side lain on		
	Left (n)	Right (n)	Total (n)
Left (n)	24	22	46
Right (n)	23	24	47
Total (n)	47	46	93

CON: conventional positioning; LiN: positioning in neutral

Measurements on each patient were made by the same investigator before and after the intervention, as excellent quality criteria exist only for intrarater reliability, not for interrater reliability (e1–e4).

The measurement procedure in this study was markedly more restrictive than that in other studies. In other studies, PROM measurements were carried out either after a large movement, after several movements, or when hard resistance was encountered at the end of mobility testing. In the present study, the joint was moved only once, and the movement was stopped immediately if the slightest resistance occurred, deviation out of the plane of movement was felt, or pain occurred. Our intention was to ensure that physically strong investigators and those who were weak would achieve comparable results. This may be why the baseline values for range of motion were lower in this study than in others (eTable 2) (e5–e7).

Results

Some of the results are shown in detail in eTables 2–5.

Additional analyses

In this section we present some sensitivity analyses and secondary analyses. Each time, the same analytical model was employed. Independent variables were the positioning approaches (two levels: LiN, CON) and the positions (five levels: supine, 30° right or left side lying, 90° right or left side lying). Baseline PROM values were included in the model as covariables. The interaction between positioning approach and position was also taken into account.

Results for patients who were unable to communicate

The investigators were told not to talk with the patients about the positioning approach assigned, to ensure that blinding was maintained. To ensure that no unblinding had occurred on the part of the patients, we conducted a sensitivity analysis that included only the noncommunicating patients (n = 79). The effect of the position was comparable to that in the primary analysis ($\Delta_{\text{PROM hips}} [\text{LiN}] - \Delta_{\text{PROM hips}} [\text{CON}] = 13.14^\circ$, p 0.03).

Effect of lying on the more affected versus the less affected side in patients with differently affected sides

To analyze whether being positioned on the more affected or the less affected side had an influence on PROM, we excluded from the analysis all patients who did not have a more strongly affected side, or for whom this was unknown, or who were lying supine. This analysis included n = 128 patients. The standard statistical model was expanded by the variable “lying on the more affected side” (two levels: yes, no). The effect of the position remained significant (p<0.001), and the condition “lying on the more affected side” had no effect (p = 0.52).

Effect of lying on the more affected versus the less affected side in hemiplegic patients

We excluded from the analysis those hemiplegic patients who did not show a more strongly affected side (n = 2) and those who were lying supine (n = 18), and thus analyzed n = 93 patients. The distribution of “lying on the hemiplegic” versus “nonhemiplegic side” was balanced (eTable 6).

If, for this subgroup, the variable “lying on the more affected side” (yes versus no) was included in the standard model, the effects of position are comparable (p<0.001), whereas “lying on the more strongly affected side” had no effect (p = 0.936).

Effect of the position on the side on which the patient lay and on the side that was uppermost

Our article uses the mean PROM of the shoulders and hips, because for passive mobility both sides are of interest, not just the one. In an additional analysis we investigated whether it makes a difference whether the measurements are carried out on the side on which the patient has been lying or on the opposite one. We excluded those patients who were lying supine and

eTABLE 7

Duration of illness ≤ versus >45 days and ≤ versus >182 days

Days	LiN (n)	CON (n)	Total (n)	Days	LiN (n)	CON (n)	Total (n)
≤ 45	50	31	81	≤ 182	88	84	172
> 45	54	81	135	>182	16	27	43
Total	112	104	216	Total	111	104	215
Missing values: n = 4				Missing values: n = 5			

CON: conventional positioning; LiN: positioning in neutral

analyzed the others (n = 173 patients). For these patients, two analyses were carried out. One used the measurement made on the side on which the patient had been positioned; the other used the measurement made on the other side. The analyses showed that the effect of the position is stable, irrespective of which measurement was used (for measurement on the side lain on: $p = 0.02$; for measurement on the other side: $p < 0.001$).

Effect of duration of illness for all patients

Since patients with a longer duration of illness are more likely to exhibit contractures than those with a

shorter duration of illness (who usually only have increased muscle tone), these patient groups were analyzed independently of each other. The dichotomized duration of illness was included in the analysis ($\leq$ versus > 45 days and $\leq$ versus > 6 months) (*eTable 7*).

There were more patients with a shorter duration of illness in the LiN group than in the CON group (χ^2 test: $\leq$ versus > 45 days: $p = 0.002$, $\leq$ versus > 182 days: $p = 0.10$). When this variable is included in the main ANCOVA, however, it turns out that the dichotomized duration of illness has no effect ($\leq$ versus > 45 days : $p = 0.996$, $\leq$ versus > 182 days: $p = 0.398$)