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Efficacy and safety of direct aspiration first pass technique versus stent-retriever thrombectomy in acute basilar artery occlusion—a retrospective single center experience

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Abstract
Introduction The study aimed to compare efficacy and safety of aspiration thrombectomy (AT) to stentriever thrombectomy (SRT) in patients with basilar artery (BA) occlusion (BAO).
Methods We retrospectively included patients with the following characteristics: acute BAO or occlusion of the intracranial vertebral artery (ICVA) and endovascular therapy (EVT) with stentriever (SRT) or aspiration thrombectomy (AT). Additional extra- but not intracranial EVT and intravenous thrombolysis (IVT) were allowed.
Results Between January 2013 and April 2016, 33 patients fulfilled the criteria (13 treated with SRT, 20 with AT). Prior to EVT, 23 (70%) patients received IVT. The proximal intracranial occlusion was ICVA in 2 patients, proximal BA in 5 patients, middle BA in 20 patients, and distal BA in 6 patients. Mean time to treatment was 334 min (95% CI 276–391 min). Procedure duration differed significantly (p = 0.002) as follows: 97 min with SRT (95% CI 69–124 min) and 55 min with AT (95% CI 43–66 min). Recanalization (arterial occlusive lesion (AOL) 2/3) was achieved in 26 patients (79%). Complete recanalization (AOL 3) happened more often with AT (75% (95% CI 65–85%)) compared to SRT (46% (95% CI 32–60%)). Conversion rate 6% (two patients). Hemorrhages occurred in 12 (36%) patients, periprocedural complications in eight (three dissections, five embolizations to new territory) (no group difference). Ten patients (30%) had a favorable outcome (mRS ≤3) at discharge; mortality rate was 24% (eight deaths) (no group difference).
Conclusion In primarily embolic BAO, aspiration thrombectomy was faster, effective and not detrimental to outcome as compared to stentriever thrombectomy. Thus, it may be justified to use aspiration thrombectomy as first-line treatment in these patients.

Keywords Stroke · Basilar artery occlusion · Endovascular treatment · Stent retriever · Aspiration thrombectomy

Introduction

Acute basilar artery occlusion (BAO) accounts for approximately 10% of all intracranial large vessel ischemic strokes. Successful recanalization of acute BAO prevents from poor clinical outcome and death [1–3]. Despite advances in the treatment of BAO, 70% of the patients remain disabled or die [4]. A meta-analysis of recent positive randomized stroke trials [5] corroborated the beneficial effect of endovascular therapy (EVT) for ischemic stroke due to anterior circulation (AC) major artery occlusion on patient outcome. These trials led to a change in guidelines, attributing the highest level of evidence to EVT for AC stroke [6]. In acute BAO, it is still unclear whether EVT is superior to standard therapy [1, 4].

In the past, rapid evolution of techniques and devices for EVT of ischemic stroke posed a challenge in the choice of the recanalization method [7]. Following recent positive EVT trials, stent retrievers emerged as the standard of care for the treatment of stroke due to large artery

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occlusions in the AC [6, 8]. However, the trials were not designed to demonstrate the superiority of one technique over the other [8]. In vitro studies have shown that stent-retriever thrombectomy (SRT) under continuous distal aspiration and primary aspiration thrombectomy (AT) led to comparable degrees of recanalization [9]. There is scant data regarding the in vivo comparison of SRT and AT in the treatment of stroke due to large artery occlusions in general [10, 11] and to BAO in particular [12, 13].

We aimed to compare the efficacy and safety of stent-retriever thrombectomy to first pass aspiration thrombectomy for EVT in patients with BAO.

Methods

This study had institutional ethics committee approval (EK 413102016), with waiver of informed consent.

Patients

We searched our thrombectomy database to identify all patients with acute BAO who underwent EVT between January 2013 and April 2016. We collected the following patient data: age and sex, cerebrovascular risk factors (arterial hypertension, diabetes mellitus, atrial fibrillation, dyslipidemia, prior stroke, prior myocardial infarction), National Institutes of Health Stroke Scale (NIHSS) score on admission, time of symptom onset, baseline and follow-up imaging (FU-imaging) modality (CT/CTA or MRI/MRA), etiology group of vascular occlusion according to the New England Medical Center Posterior Circulation Registry (NEMC-PCR) [14], and if intravenous thrombolysis (IVT) was given.

Patients fulfilling the following criteria were included in the study: (1) presence of a BAO or an occlusion of the intracranial vertebral artery (ICVA, V4-segment) leading to a BAO on digital subtraction angiography (DSA) and (2) EVT with SRT or AT. Additional extracranial EVT, e.g., percutaneous transluminal angioplasty (PTA) or stenting for vertebral artery (VA) origin stenosis and IVT prior to EVT, were no exclusion criteria. However, we excluded patients in whom additional intracranial angioplasty or a permanent stent were necessary to maintain the recanalization result attained by thrombectomy.

According to the institutional protocol, patients were considered for EVT if (1) non-contrast CT or MRI excluded an intracranial hemorrhage and if (2) CTA or MRA demonstrated an acute occlusion of the basilar artery. No upper age, NIHSS score, or time limit was used when selecting patients for EVT.

Image analysis

Baseline images, DSA, and follow-up images were reviewed in consensus by three readers blinded to clinical and procedural information.

We assessed the following imaging parameters: infarct extent using the posterior circulation Acute Stroke Prognosis Early CT score (pc-ASPECTS) applied to CTA-source images (at baseline), non-contrast CT (follow-up), or MRI diffusion weighted images (baseline and follow-up) depending on availability. On FU-imaging, we rated hemorrhagic complications according to the Heidelberg bleeding classification [15].

We determined the target arterial occlusion (intracranial vertebral artery (ICVA), proximal, middle and distal basilar artery (BA), and posterior cerebral artery (PCA; P1-segment only)) and extent of the thrombus (posterior circulation clot burden score, see below). Basilar artery subdivision followed the suggestion of Archer et al. [16]: the proximal BA extends from the junction of the two VA to the origin of the anterior inferior cerebellar artery (AICA), the middle BA from the AICA origin to the origin of the superior cerebellar artery (SCA), and the distal BA starts above the SCA and ends at the PCA.

We rated the thrombus load with a 10-point posterior circulation clot burden score (pc-CBS) built in analogy to the CBS [17]. The pc-CBS allots the intracranial segments of the posterior circulation (PC) arteries 10 points for the presence of contrast opacification in CTA or flow-signal on MRA. One point each is subtracted for absence of contrast opacification (CTA) or flow-signal (MRA) in the V4-segments of the VA and the P1-segments of the PCA, and two points each for the proximal, middle, and distal segments of the BA. Partial filling defects suggesting stenosis or non-occlusive thrombus are rated as patent. Aplastic segments of the distal VA and the P1-segments will be scored as abnormal. A pc-CBS of 10 indicates absence of an occlusion; a score of 0 indicates occlusion of all major intracranial PC arteries.

Endovascular treatment

For EVT, we used stent retrievers aided by a distal aspiration catheter at the thrombus and primary AT, also referred to as a direct aspiration first pass technique for stroke thrombectomy (ADAPT) [18]. The treating interventionist chose the sequence and method of the thrombectomy. Five interventionists with 3, 5, 6, 11, and 15 years of practice in neurointerventions treated the patients.

The following details were documented: femoral artery puncture time (start of treatment), the most proximal intracranial arterial occlusion (the target occlusion [19]), device (stent retriever or aspiration catheter type and size), number of retrieval/aspiration passes, time of recanalization, local recanalization result according to the arterial occlusive lesion

(AOL) scale [19, 20], and procedural complications. We calculated the difference (AOL_{diff}) between the occlusion grading before (AOL_{pre}) and after the intervention (AOL_{post}) to document treatment effect. Successful recanalization, defined as an AOL_{diff} grade of 2 or 3, was the variable of interest. SRT or AT was considered the respective first-line strategy if either was attempted first. We noted any derivation from these techniques and whether it was necessary to convert from one to another.

Functional outcome and safety

Functional neurological outcome was assessed using the modified Rankin Scale (mRS) score at discharge from the hospital. Favorable outcome was defined as mRS scores of ≤3 [1]. Neurological outcome at discharge was the variable of interest regarding clinical efficacy. The type and grade of intracranial hemorrhage [15] and the procedural complications were recorded as safety variables.

Statistical analysis

Distributions of the continuous variables were tested for normality. Continuous variables are presented as mean ± standard deviation (SD) (normal distribution) or as median with its interquartile range (IQR) (skewed distribution). Categorical variables are presented as percentages. We performed bivariate comparisons for baseline characteristics and outcome variables between the SRT and AT group by using the $\chi 2$ test or Fisher's exact test for binary outcomes as appropriate and Student's t test (or the Mann-Whitney U test for non-Gaussian distributions) for continuous variables. For all statistical analyses, a two-tailed $p < 0.05$ was considered significant. We analyzed the data with IBM SPSS Statistics Version 23.

Results

Patients

In total, 61 patients (39 (64%) men; median age 65 years, range 25–85 years) with PC stroke were eligible for EVT in our department between January 2013 and April 2016. For the purpose of the study, we excluded all patients who had recanalized as demonstrated by the first angiographic series ($n = 1$), in whom we could not access the target arterial occlusion ($n = 6$), who only received intra-arterial rtPA ($n = 2$) or PTA ($n = 1$), or who were treated with AT ($n = 10$) or SRT ($n = 8$) and any additional intracranial treatment (supplemental table 1). Finally, we included 33 patients in the study. Thirteen patients were treated with stent-retriever thrombectomy (SRT group) and 20 with aspiration thrombectomy (AT group). Prior to EVT, 23 (70%) patients received IVT, 12 (60%) in the AT, and 11 (85%) in the SRT group (no significant group difference). Baseline characteristics in the two groups differed only regarding the incidence of diabetes mellitus, with more diabetic patients in the AT group (Table 1).

Baseline imaging and target arterial occlusion

Before EVT, 32 (96%) patients received a non-contrast CT and CTA and one patient received a MRI and MRA. In two patients, the external CTA was not available at the time of study related image assessment. Baseline imaging parameters (Table 1) did not significantly differ between groups.

According to the DSA, the target occlusion was the intracranial vertebral artery in 2 patients, the proximal BA in 5 patients, the middle BA in 20 patients, and the distal BA in 6 patients (Table 1). CTA showed a corresponding occlusion in the respective vessel segments in all available images and revealed a patent distal BA-segment in only 2 out of 20 patients with middle BA occlusion proven by DSA.

Endovascular treatment

We performed EVT in intubated patients under general anesthesia. We treated 13 patients with primary SRT (pREset, phenox GmbH, Bochum, Germany; Separator 3D, Penumbra Inc., Alameda, CA, USA; Solitaire FR, ev3, Irvine, CA, USA), combined with distal aspiration at the proximal end of the stent retriever via a 4.1F aspiration catheter (041 Reperfusion Catheter, Penumbra Inc., Alameda, CA, USA) in 12 patients and with a 6F-guiding catheter in the V2-segment of the VA in one patient (Table 2). In the AT group, we treated 20 arterial occlusions with first pass AT using either the 041 Reperfusion Catheter with an inner lumen of 0.041 in. ($n = 10$), a 5.4F aspiration catheter with a distal inner lumen of 0.060 in. (5MAX ACE Reperfusion Catheter, Penumbra Inc.) ($n = 9$), or both catheters sequentially ($n = 1$). Mean time from onset of symptoms to groin puncture (time to treatment, TTT) was 334 min (95% CI 276–391 min) (Table 1). The time of symptom onset was unknown in one patient. TTT did not differ between treatment groups.

Recanalization

The duration of the intervention (mean time from groin puncture to final recanalization) differed significantly between groups ($p = 0.002$) as follows: 97 min in the SRT group (95% CI 69–124 min) versus 55 min in the AT group (95% CI 43–66 min) (Table 2). Mean time from symptom onset to recanalization (time to recanalization, TTR) was 407 min (95% CI 348–465 min) (Table 2). TTR did not differ between treatment groups. Successful recanalization (AOL 2 and 3) was achieved in 9 (69%) patients treated with SRT and in 17

Table 1 Baseline characteristics of the patient cohort and by treatment groups

		Total cohort (n = 33)				Treatment groups					
						Stentriever (n = 13)			Aspiration (n = 20)		
		n (%)				n (%)			n (%)		
Age	(n/mean/SD/95%CI)	33	63	13	58.4–67.5	13	63.2	54.1–72.3	20	62.8	57.4–68.2
Sex (male)		22 (67)				8 (62)			14 (70)		
Admission NIHSS	(n/median/IQR)	33	22	25.5		13	25	19	20	18	28
IVT prior to EVT		23 (70)				11 (85)			12 (60)		
Vascular risk factors (n = 20)	Previous stroke	0				0			0		
	Dyslipidemia	6 (30)				3			3		
	Diabetes mellitus	11 (55)				1			10		
	Atrial fibrillation	8 (40)				2			6		
Arterial hypertension		18 (90)				5			13		
Previous myocardial infarction		0				0			0		
NEMC-PCR group of basilar artery (BA) occlusive disease[a]	Group A	2 (6)				0			2		
	Group B	2 (6)				2			0		
	Group C	29 (88)				11			18		
Target occlusion (DSA)	Intracranial VA	2 (6)				1			1		
	Proximal BA	5 (15)				2			3		
	Middle BA	20 (61)				9			11		
	Distal BA	6 (18)				1			5		
pc-ASPECTS	(n/median/IQR)	31	7	5.5		11	6.5	5	20	7.5	5
pc-CBS	(n/median/IQR)	30	5	2		11	5	2	19	6	4
AOL pre	(n/median/IQR)	33	0	0		13	0	0	20	0	0
	AOL 0	30				12			18		
	AOL 1	3				1			2		
Time (min) to treatment	(n/mean/SD/95%CI)	32	334	159	276–391	13	353	239–466	19	321	253–389

[a] New England Medical Center Posterior Circulation Registry (NEMC-PCR) basilar artery occlusive disease groups [14]. Group A, isolated basilar artery disease; Group B, basilar artery involvement as part of widespread posterior circulation atherosclerosis; Group C, embolism to the basilar artery

(85%) patients treated with AT (Table 2) but did not significantly differ between groups. However, complete recanalization (AOL 3) was achieved more often with AT (75% (95% CI 65–85%)) compared to SRT (46% (95% CI 32–60%)).

In two patients of the AT group, we had to convert from one device to another. In one patient, AT with a 4.1F catheter failed. After replacing it with a 5MAX ACE, we achieved full recanalization (AOL 3). In another case of unsuccessful AT (4.1F catheter), we changed to SRT which was equally unsuccessful (AOL 0).

Periprocedural complications

As periprocedural complications, we noted a dissection of the VA without hemodynamic impairment in three patients (all SRT group) and an embolization to previously unaffected vessel territories in five patients (three in SRT group, two in AT group).

Clinical and imaging outcome

A favorable outcome (mRS ≤3) at discharge was observed in 10 patients (30%). The proportion of patients with a favorable outcome was higher in the AT group (not significant; Table 2). Mortality rate was 24% (eight patients; four deaths per group: 31% in SRT group; 20% in AT group; not significant).

For FU-imaging, 14 patients had a non-contrast CT and 19 patients received a MRI. Median time to first FU-imaging was 19 h after the end of the intervention (IQR 14 1/2 h). Final infarct sizes are presented in Table 2. No patient with a pc-ASPECTS of 7–10 on FU-imaging died until discharge, while all patients who died during their hospital stay showed a pc-ASPECTS of 0–6 on FU-imaging.

Intracranial hemorrhagic complications occurred in 12 (36%) patients (Table 2). Two of them had a combination of subarachnoid hemorrhage (SAH) and either hemorrhagic infarction type 1 (HI1) or parenchymatous hematoma type 1 (PH1). All three patients with a SAH died. All patients with

Table 2 Treatment results and outcomes by treatment group

		Total cohort (n = 33)				Treatment groups					
						Stent retriever (n = 13)			Aspiration (n = 20)		
		n (%)				n (%)			n (%)		
Stent retriever	Solitaire	1				1 w/o distal aspir.					
	Preset	6				6 + distal aspir.					
	3D–Seperator	6				6 + distal aspir.					
Aspiration catheter	041 Reperf. cath.	22				(12 + dist. aspir.)			10		
	5MAX ACE	9							9		
	041+5MAX ACE	1							1		
Adverse events	Dissection	3 (9.1)				3			0		
Embolization to new territory (ENT)		5 (15.2)				3			2		
Recanalization (AOL diff.)	(n/median/IQR)	33	3	1		13	2	3	20	3	1
	AOL 0	5 (15.2)				4 (31)			1 (5)		
	AOL 1	2 (6.1)				0			2 (10)		
	AOL 2	5 (15.2)				3 (23)			2 (10)		
	AOL 3	21 (63.6)				6 (46)			15 (75)		
Time (min) to recanalization	(n/mean/SD/95%CI)	32	407	163	348–465	13	450	340–559	19	377	306–448
Duration of intervention (min)	(n/mean/SD/95%CI)	33	71	39	57–85	13	97	69–124	20	55	43–66
Follow-up imaging modality	CT	19				8			11		
	MRI	14				5			9		
Final infarct size (pc-ASPECTS)	(n/median/IQR)	33	5	3.5		13	4	5	20	6	4
Hemorrhagic infarction (HI)	HI1	5 (15.2)				1 (8)			4 (20)		
	HI2	4 (12.1)				1 (8)			3 (15)		
Parenchymatous hematoma (PH)	PH1	1 (3)				1 (8)			0		
	PH2	0				0			0		
	Remote PH	1 (3)				0			1 (5)		
Subarachnoid hemorrhage (SAH)		3 (9.1)				1 (8)			2 (10)		
Outcome at discharge	Favorable—mRS 0–3	10 (30.3)				1 (8)			9 (45)		
	Poor—mRS 4–5	15 (45.5)				8 (61)			7 (35)		
	Deceased—mRS 6	8 (24.2)				4 (31)			4 (20)		

HI1 survived but the one patient with additional SAH. Three of four patients with HI2 deceased as did the patient with PH1 (and simultaneous SAH). Hemorrhagic complications did not differ between groups.

Discussion

We could show that AT recanalized faster and more complete in our selected cohort of BAO patients, in comparison to SRT aided by distal aspiration. These techniques have not been compared before.

The superiority of EVT in BAO could not be shown [1] and is under further study [4]. However, in the anterior circulation, EVT for ischemic stroke due to large artery occlusion is proven in eligible patients (class I grade of recommendation, level of evidence A) [6]. And stent retrievers should be used for thrombectomy (class I, level A). Converging results in efficacy and safety of SRT and AT makes it reasonable to consider devices other than stent retrievers in selected cases (class IIb, level B-NR) [6]. However, there is no agreement as to which device or technique is best and recent trials were not designed to answer this question [8]. Non-randomized observations report non-inferiority of AT compared to SRT. The observed advantages of AT are faster procedures, higher rates of complete recanalization, and equal or better outcomes [10, 11, 18, 21].

Two studies compared SRT and AT in the BAO and found comparable procedural and clinical outcomes [12, 13]. One study reported faster procedures and more complete recanalizations with AT, as reproduced here. However, neither distal aspiration along with a stent retriever nor last generation large bore aspiration catheters were used [12]. The other study did not report procedural details [13]. We used large bore

aspiration catheters in the AT group, and all but one patient in the SRT group were treated with additional aspiration directly proximal to the stent retriever. In vitro studies suggest a conceptual advantage when using stent retrievers in combination with distal aspiration [22]. In vivo, this combination shortens the thrombectomy procedure in acute BAO [23]. Anatomically, this technique makes sense in the PC, as a guiding catheter in one VA may only reverse the flow in that artery without affecting the basilar thrombus due to competing flow from the other VA [24]. With distal aspiration, the thrombus captured in the stent and the aspiration catheter may be removed under controlled suction. Moreover, modern large bore aspiration catheters enable us to even attempt recanalization without any other device, in both the AC [10, 18, 21] and PC [12].

We had to convert from AT to SRT in only one patient (3%). Typical conversion rates are 44–22% in mainly AC strokes not differentiating between the carotid and vertebrobasilar circulation [21, 25]. Reported conversion rates in PC stroke are 0% [12] and 48% [13]. In our experience, lower conversion rates are typical in the PC as the access to the culprit lesion via the VA is easier, thanks to the lack of a comparable anatomical obstacle as the carotid syphon. However, if needed, the transition to SRT is easy in first-line AT as the aspiration catheter is already close to the occlusion. Another advantage of AT is its proximal mode of action. Aspiration allows to safely removing the clot without the necessity to first penetrate a diseased vessel segment, as in PC more often than in the AC, there can be an occlusion due to local arteriosclerosis, predominantly in the proximal BA-segments [14].

Occlusions involving the distal BA-segment are mostly embolic, more amenable to both IVT and EVT, and have a better prognosis if successfully recanalized as compared to occlusions in proximal BA-segments [2, 26]. As we excluded patients requiring intracranial EVT other than SRT or AT, a majority of the study patients (80%) suffered from embolic occlusion involving the mid to distal BA (Table 1).

In our study, a rate of 79% AOL 2/3 recanalizations is contrasted by a rate of moderate outcome (mRS ≤3) of 30% at discharge. The in-hospital mortality was 24%. Intracranial hemorrhagic complications occurred in 12 (36%) patients and were associated with six deaths. Two registries of acute BAO treatment [1, 27] reported similar recanalization rates of 72 and 79%, moderate outcome (mRS ≤3) in 32% (at 1 month) and 42% (after 90 days), a mortality rate of 36 and 35%, and hemorrhages in 14 and 6%, respectively. A meta-analysis of SRT studies in acute BAO (15 studies, 312 patients) reported a 90-day favorable outcome (mRS ≤2) in 42% (95% CI 36–48%), recanalization in 81% (95% CI 73–87%), 30% mortality (95% CI 25–36%), and symptomatic hemorrhages in only 4% (95% CI 2–8%) [26]. Whether this increase in good outcome along with a reduction in hemorrhage truly heralds a leap forward in EVT for BAO or mirrors study quality (non-randomized, self-reported, single center, small numbers) has to be proven in randomized trials.

Recanalization rates of 80% are typically reported in EVT for acute BAO [1, 12, 13, 26, 27]. However, which scale should be used remains unresolved. Most of the studies used the TIMI [1, 3] or TICI [12, 13] score to assess "recanalization" but neither was validated in the PC [20] and both are reperfusion scales [19]. In a recent study, the AOL scale reliably classified BAO recanalization, while the mTICI score failed to achieve substantial inter-observer agreement [20]. Consequently, we used the AOL scale as it addresses device efficiency at the occlusion [19]. Contrary to the AC [28], there is no validated dichotomization cut-off for the recanalization result in the PC to predict good outcome.

Due to missing data, we could not adjudicate the relationship between hemorrhage and possible clinical deterioration [15]. However, hemorrhage was associated with larger final infarct and death; all patients (except one patient with a remote hemorrhage) with a hemorrhagic complication had a pc-ASPECTS <7 as did all patients who died in hospital. In accordance, the risk of hemorrhagic infarction in stroke due to BAO was described as largely determined by the extension of ischemic changes on admission CT [29, 30]. Of note, there is no classification of bleeding events after ischemic stroke which considers the specifics of the PC [26].

Limitations

The study has the limitations of a retrospective design and was not powered for multivariable analysis and contains unbalanced data. A study sample size was not calculated, and we could not exclude some differences being overlooked due to the lack of adequate statistical power. At best, we were able to generate hypotheses.

To compare procedural complications would not be meaningful as in most patients of the SRT group an additional aspiration catheter was used which may have caused the complication.

There are three main sources of bias which may influence the results. The first is sampling, as we excluded all patients with additional treatments other than AT or SRT (supplemental table 1). The group of excluded patients (n = 28) significantly differed from the study group (n = 33); the intervention took longer; good recanalization was achieved less often; mortality was higher. The second bias is time, as we report a longitudinal observation of changing treatment techniques (supplemental table 1). AT was introduced when large bore aspiration catheters became available. Before, SRT with distal aspiration was used. Thus, the observed effects may in part be due to training. The third is selection bias, as the study population turned out to have mainly embolic occlusions (NEMC-PCR disease group C;

Table 1, supplemental table 2). However, by homogenizing the study population in regard to etiology, the comparison of the two treatments may be more robust. We chose the NEMC-PCR groups as they are specifically derived from the posterior circulation [14].

Compliance with ethical standards

Funding No funding was received for this study.

Conflict of interest JCG has speaking engagements with Penumbra Inc.

Ethical approval All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent For this type of study formal consent is not required.

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