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Age as a Risk Factor for Intraoperative Periprosthetic Femoral Fractures in Cementless Hip Hemiarthroplasty for Femoral Neck Fractures: A Retrospective Analysis

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Background: Understanding the risk factors and outcomes of intraoperative periprosthetic femoral fractures (IPFF) during hip arthroplasty is crucial for appropriate perioperative management. Previous studies have identified risk factors for IPFF in total hip arthroplasty patients, but data for hip hemiarthroplasty (HA) is lacking. The aim of this study was to determine the age associated with increased rates of IPFF in patients undergoing HA.

Methods: We retrospectively reviewed patients aged 65 years and above who underwent a cementless HA for a displaced femoral neck fracture and had a minimum of 1-year follow-up. Patients were stratified into five age groups (65–79, 80–84, 85–89, 90–94, and ≥ 95 years) and further divided into two subgroups (under 95 years and 95 years or older). The presence, location, and treatment of IPFF, as well as the effect of IPFF on the postoperative weight-bearing status, were compared between groups. A multivariate logistic regression was also performed. A total of 1,669 met the inclusion criteria and were included in the study.

Results: The rates of IPFF were significantly higher for patients 95 years or older (p = 0.030). However, fracture location (greater trochanter fractures, p = 0.839; calcar fractures, p = 0.394; and femoral shaft fractures p = 0.110), intraoperative treatment (p = 0.424), and postoperative weight-bearing status (p = 0.229) were similar between the groups. While mortality and nonorthopedic-related readmissions were significantly higher for patients 95 years or older, orthopedic-related readmissions (p = 0.148) and revisions at the latest follow-up (p = 0.253) were comparable between groups. In a regression analysis, age over 95 years (odds ratio, 2.049; p = 0.049) and body mass index (odds ratio, 0.935; p = 0.016) were independently associated with IPFF.

Conclusions: The findings of this study suggest that age over 95 years is a significant, independent risk factor for IPFF in patients undergoing cementless HA. Although we were unable to show an impact on perioperative outcomes and orthopedic complications, when operating on patients 95 years or older, surgeons should be aware of the increased risk of IPFF and consider the use of stem designs and fixation types associated with decreased IPFF rates.

Keywords: *Hip hemiarthroplasty, Intraoperative fracture, Periprosthetic femoral fracture*

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Femoral neck fractures (FNFs) in the elderly are growing in incidence and represent a significant source of patient morbidity and mortality, placing a burden on healthcare systems worldwide.[1] Displaced FNFs are managed surgically by either total hip arthroplasty (THA) or hip hemiarthroplasty (HA)[2] for lower mortality and morbidity rates, less complications, and improved rehabilitation when

compared to nonoperative treatment.[3,4] Intraoperative periprosthetic femoral fracture (IPFF) is a well-described iatrogenic complication of these procedures.[5,6] Although most IPFFs are simple nondisplaced fractures,[7] if they are not identified intraoperatively or not managed appropriately, they may lead to adverse outcomes, such as early loosening or increased risk of revision surgery.[5,8]

Previous studies have identified risk factors for IPFF in THA patients including age,[9-12] female sex,[9-11] osteoporosis,[9,12] and rheumatoid arthritis.[12] However, most of these studies examined the risks for IPFF during primary and/or revision elective THA, and risk factors for IPFF during HA are rarely described in the current body of literature. Understanding the risk factors for these patients is crucial, especially when considering that patients who undergo hip arthroplasty as treatment for FNF are already at high risk for IPFF, as they are significantly older and have more medical comorbidities than patients undergoing surgery as an elective procedure.[13] Moreover, hip arthroplasty for FNF typically requires urgent management, leading to challenges in patient optimization[14] and resulting in inferior postoperative outcomes.[14-16]

To date, there are only a few studies assessing IPFF during HA for displaced FNF,[17-20] and to our knowledge, there are no studies assessing the association between patients' age and IPFF in patients undergoing HA with cementless femoral stems. The aim of our study was to assess the risk of IPFF in cementless HA for displaced FNF and compare the association between IPFF rates and age in these patients. We hypothesized that increasing age would be associated with increased rates of IPFF.

METHODS

The present study received approval from Institutional Review Board of Tel Aviv Medical Center (No. TLV-0566-23). The requirement for informed consent was waived due to retrospective nature of this study.

Study Design

After receiving approval for this study from our Institutional Review Board, we retrospectively reviewed all patients 65 years of age and older who underwent a cementless bipolar HA (BHA) for displaced FNF between September 2018 and January 2021 at our urban, tertiary care, academic hospital. Only patients who had a minimum follow-up of 12 months were included in the study. Patients who underwent BHA for an indication other than FNF (i.e., oncologic) and patients who did not meet follow-up criteria were excluded from the study. Patients were stratified into five age groups for comparison of patients' demographics, surgery characteristics, and treatment outcomes across the groups: ages 65–79, 80–84, 85–89, 90–94, and 95 years or above. The decision to stratify patients 65 to 80 years of age to the same group was based on the study published by Bruggemann et al.,[10] suggesting age over 80 years as a risk factor for IPFF. After the initial analysis, the total cohort was further divided into two subgroups: those under 95 years old and those 95 years old and older. Surgery characteristics and treatment outcomes were additionally compared between these two subgroups.

Data Collection

The data were assessed by reviewing electronic clinical medical records. Patient baseline characteristics, including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, and Charlson comorbidity index (CCI) were collected. Mortality data were available in the hospital database by synchronization with the national mortality registry. Surgery duration was assessed from surgical notes and was calculated as the time between surgical incision and the end of surgical wound closure (skin-to-skin). The bone quality of the proximal femur was assessed from the preoperative X-ray using the Dorr classification[21] and was obtained independently by two board-certified orthopedic surgeons (YW and AG), one of whom is a fellowship-trained joint reconstruction surgeon. Interobserver correlation analysis was performed for data validation.

Data on IPFF were collected by a manual chart review of the electronic medical files and postoperative imaging and included the presence of IPFF, location of the fractures, intraoperative treatment, postoperative physical therapy protocol, and whether full weight-bearing was allowed. The location of the fracture was categorized as greater trochanter (GT) when involving the GT and as femoral shaft or calcar when involving the calcar with or without extension of the fracture distal to the lesser trochanter, respectively. The results were presented according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational research studies.

Surgery

All patients were operated using an anterolateral approach by either an orthopedic resident (postgraduate year 5–6) or a fellowship-trained joint reconstruction or trauma specialist. For all patients, a cementless femoral stem was used. According to our department's protocol, full weight-bearing ambulation and range of motion exercises after

BHA start on postoperative day 1. For patients who had an IPFF, the decision on weight-bearing and range of motion was at the discretion of the surgeon.

Outcome Parameters

The primary outcomes included the presence, location, and treatment of IPFF, as well as the effect of IPFF, on the postoperative physical therapy protocol. Secondary outcomes included perioperative data, such as surgery duration, 30-day and 90-day readmission rates, mortality at 30 days, 90 days, and 1 year, and rates of revisions of any cause at the latest follow-up.

Statistical Analyses

Demographic and clinical characteristics were described as means with ranges or standard deviations for continuous variables and frequencies with percentages for categorical variables. Differences in continuous variables were analyzed using the analysis of variance tests or independent samples *t*-tests, as appropriate. For categorical variables, differences were analyzed using chi-square and Fisher-exact analyses. For interobserver correlation, the Spearman rank correlation[22] was used and showed a correlation coefficient of 0.91. To account for any potential confounders and to evaluate factors associated with IPFF, we ran a multivariate logistic regression model that assessed all variables deemed statistically different between the cohorts. All data analyses were performed using IBM SPSS ver. 25 (IBM Corp.). Statistical significance was set at $p < 0.05$.

RESULTS

Of the 1,669 patients that were included in the final analyses, 460 (27.6%) were under the age of 80 years, 433 (25.9%) were 80–84 years of age, 441 (26.4%) were 85–89 years of age, 259 (15.5%) were 90–94 years of age, and 76 (4.6%) were 95 years of age or older. The majority of patients across all age groups were women, and the rate of women patients was comparable between groups ($p = 0.732$). Patients 95 years or older had significantly more comorbidities, as represented by both higher rates of patients with ASA scores of 3 and 4 ($p = 0.004$) and by higher mean CCI scores ($p < 0.001$). Bone quality, assessed by the Dorr classification, was significantly worse for patients 95 years or older ($p = 0.027$). The rate of patients with Dorr C steadily grew with age (Table 1).

Intraoperative Periprosthetic Femoral Fractures

While rates of IPFF remained constant across age groups

Table 1. Patient Baseline Characteristics by Age Group

Variable	Age group (yr)					*p*-value
	65–79 (n = 460)	80–84 (n = 433)	85–89 (n = 441)	90–94 (n = 259)	≥ 95 (n = 76)	
Female sex	302 (65.6)	285 (65.8)	284 (64.3)	166 (64.0)	44 (57.9)	0.732
BMI (kg/m^2)	24.8 (14.2–42.9)	24.5 (15.1–39.1)	24.0 (14.7–34.9)	23.5 (15.4–36.3)	23.9 (15.1–36.7)	0.005
ASA score						0.004
1	9 (1.9)	6 (1.3)	3 (0.6)	0	0	
2	186 (40.6)	163 (37.9)	164 (37.7)	70 (27.5)	22 (29.3)	
3	229 (50.0)	238 (55.4)	229 (52.7)	162 (63.7)	45 (60)	
4	34 (7.4)	22 (5.1)	38 (8.7)	22 (8.6)	8 (10.7)	
Missing	2 (0.7)	4 (1.4)	7 (1.5)	5 (1.9)	1 (1.3)	
CCI	3.8 ± 1.5	4.6 ± 1.4	4.9 ± 1.3	5.5 ± 1.5	6 ± 1.4	< 0.001
Dorr classification						0.027
A	39 (8.5)	46 (10.6)	41 (9.3)	34 (13.1)	7 (12.5)	
B	148 (32.2)	156 (36.0)	161 (36.5)	99 (38.2)	35 (62.5)	
C	29 (6.3)	44 (10.2)	48 (10.9)	52 (20.1)	14 (25.0)	

Values are presented as number (%), median (range), or mean ± standard deviation.
BMI: body mass index, ASA: American Society of Anesthesiologists, CCI: Charlson comorbidity index.

for patients 95 years or older and younger, the rates of IPFF for patients over the age of 95 years were almost twice as high, compared to their counterparts (Fig. 1), despite not being statistically significant. The locations of the IPFF including GT, calcar, and femoral shaft were comparable across the age groups ($p = 0.817$, $p = 0.830$, and $p = 0.718$, respectively), as well as the intraoperative treatment ($p = 0.970$) and postoperative weight-bearing status ($p = 0.899$) (Table 2).

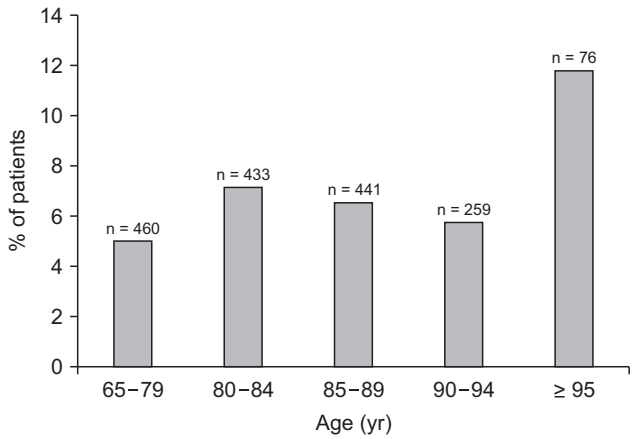

Fig. 1. Rates of intraoperative periprosthetic femoral fractures by age group.

When the age of 95 years was used as the cutoff between groups, the rates of IPFF in patients over 95 years old were significantly higher than those of patients under 95 years of age (11.8 vs. 6.1%, $p = 0.030$). There was no difference in fracture location (GT fractures, $p = 0.839$; calcar fractures, $p = 0.394$; and femoral shaft fractures, $p = 0.110$), intraoperative treatment ($p = 0.424$), and postoperative weight-bearing status ($p = 0.229$) between groups (Table 3).

A multivariate logistic regression has shown that age over 95 years (odds ratio, 2.049; 95% confidence interval [CI], 1.067–4.232; $p = 0.049$) was associated with an increased risk of IPFF. Conversely, increased BMI (odds ratio, 0.935; 95% CI, 0.885–0.987; $p = 0.016$) was associated with lower IPFF risk. However, patients' ASA and CCI scores ($p = 0.467$ and $p = 0.268$, respectively), as well as their Dorr classification ($p = 0.902$), were not found to be associated with IPFF risk (Table 4).

Perioperative and Postoperative clinical Outcomes

The mean surgery duration was similar between patients over and under 95 years of age ($p = 0.159$). The rates of mortality at 30 days, 90 days, and 1-year postoperatively

Table 2. Primary Outcomes Stratified by Age Group

Variable	Age group (yr)					*p*-value
	65–79 (n = 460)	80–84 (n = 433)	85–89 (n = 441)	90–94 (n = 259)	≥ 95 (n = 76)	
IPFF	23 (5.0)	31 (7.1)	29 (6.5)	15 (5.7)	9 (11.8)	0.198
Fracture location						
Greater trochanter	14 (60.9)	16 (51.6)	18 (62.1)	14 (93.3)	6 (66.7)	0.817
Calcar	14 (60.9)	20 (64.5)	22 (75.9)	12 (80.0)	5 (55.6)	0.830
Femoral shaft	8 (34.8)	7 (22.6)	8 (27.6)	6 (40.0)	0	0.718
Intraoperative treatment						0.970
No treatment needed	2 (8.7)	1 (3.2)	0	0	0	
Fixation with wires/cable	20 (87.0)	28 (90.3)	28 (96.6)	14 (93.3)	8 (88.9)	
Stem revision	1 (4.3)	2 (6.5)	1 (3.4)	1 (6.7)	1 (11.1)	
Postoperative PT						0.899
FWB	22 (95.7)	30 (96.8)	27 (93.1)	14 (93.3)	9 (100.0)	
PWB	1 (4.3)	1 (3.2)	1 (3.4)	0	0	
NWB	0	0	1 (3.4)	1 (6.7)	0	

Values are presented as number (%).
IPFF: intraoperative periprosthetic femoral fracture, PT: physical therapy, FWB: full weight-bearing, PWB: partial weight-bearing, NWB: no weight-bearing.

(p = 0.0.015, p = 0.011, and p = 0.003, respectively), as well as 90-day readmission (p = 0.001), were significantly higher for patients 95 years of age and older. While rates of nonorthopedic-related readmissions for these patients were significantly higher (p = 0.004), rates of orthopedic-related readmissions were comparable between groups (p = 0.148). Similarly, rates of revisions at the latest follow-up (p = 0.253) and distribution of the indications for these revisions (p = 0.633) did not differ between the groups (Table 5).

DISCUSSION

To the best of or knowledge this is the first study to assess age as a risk factor for IPFF in patients undergoing cementless HA for FNF. The main findings of our study are as follows: (1) Rates of IPFF remained constant for all groups of patients under the age of 95 years and increased significantly for patients 95 years of age and older. (2) The location of the fracture, as well as intraoperative treatment, was similar regardless of the age group. (3) The increased rates of IPFF in patients 95 years of age and older

Table 3. Primary Outcomes Stratified by Age over and under 95 Years

Variable	Age group (yr)		*p*-value
	65–94 (n = 1,593)	≥ 95 (n = 76)	
IPFF	98 (6.1)	9 (11.8)	0.030
Fracture location			
Greater trochanter	62 (63.3)	6 (66.7)	0.839
Calcar	68 (69.4)	5 (55.6)	0.394
Femur shaft	29 (29.6)	0	0.110
Intraoperative treatment			0.424
No treatment needed	3 (3.1)	0	
Fixation with wires/cable	90 (91.8)	8 (88.9)	
Stem revision	5 (5.1)	1 (11.1)	
Postoperative PT			0.229
FWB	93 (94.9)	9 (100.0)	
PWB	3 (3.1)	0	
NWB	2 (2.0)	0	

Values are presented as number (%).
IPFF: intraoperative periprosthetic femoral fracture, PT: physical therapy, FWB: full weight-bearing, PWB: partial weight-bearing, NWB: no weight-bearing.

Table 5. Secondary Outcomes Stratified by Age over and under 95 Years

Variable	Age group (yr)		*p*-value
	65–94 (n = 1,593)	≥ 95 (n = 76)	
Surgery duration (min)	72 (30–240)	68 (32–180)	0.159
Mortality			
30-Day	84 (5.2)	9 (11.8)	0.015
90-Day	151 (9.4)	14 (18.4)	0.011
1-Year	301 (18.9)	25 (32.9)	0.003
90-Day readmission	240 (15.1)	22 (28.9)	0.001
Orthopedic related	27 (1.6)	3 (3.9)	0.148
Nonorthopedic related	213 (13.4)	19 (25.0)	0.004
Revisions at latest follow-up	91 (5.7)	2 (2.6)	0.253
Indication for revision			0.633
Periprosthetic fracture	57 (3.4)	1 (1.3)	
Periprosthetic joint infection	13 (0.7)	0	
Dislocation	21 (1.2)	1 (1.3)	

Values are presented as median (range) or number (%).

Table 4. Logistic Regression Model for Intraoperative Fractures

Variable	Odds ratio	Coefficient	Standard error	95% Confidence interval	*p*-value
BMI	0.935	–0.068	0.028	0.885–0.987	0.016
ASA score	1.124	0.117	0.160	0.821–1.539	0.467
CCI	1.068	0.066	0.059	0.951–1.200	0.268
Age over 95 years	2.049	0.717	0.370	1.067–4.232	0.049
Dorr classification	1.026	0.026	0.208	0.683–1.543	0.902

BMI: body mass index, ASA: American Society of Anesthesiologists, CCI: Charlson comorbidity index.

did not impact the postoperative weight-bearing status, orthopedic-related readmissions, and the need for further revisions.

The findings of our study, which suggest that older age is a risk factor for IPFF, are in agreement with previous studies identifying age as a risk factor for IPFF in patients undergoing THA.[9,10] Lindberg-Larsen et al.[9] demonstrated a significant increase in the relative risk for IPFF of 1.4 per 10 years for patients undergoing a cementless THA. Conversely, our findings did not show a continuous increase in the risk for IPFF with age, although we were able to identify a cutoff age at which patients are at risk for IPFF. Similarly, Bruggemann et al.[10] proposed age above 80 years as a cutoff by which people should be considered at increased risk for IPFF. Differences within the patient population, namely procedure type and the diagnosis for surgery, may explain the discrepancy in our findings. While in the above-mentioned studies, the patients were undergoing primary THA in which the surgical indication was primarily due to osteoarthritis,[9,10] patients in our study underwent HA for FNF.

As FNF are associated with poor bone quality,[23] which has been previously shown to be a risk factor for IPFF,[9,12] our patients were more predisposed to IPFF, which may result in an increased age requirement to detect a difference in risk between the groups. The increased risk of patients in our cohort is supported by reported rates of IPFF in THA patients, ranging from 1.0% to 3.2%,[9,10,24] considerably lower than the rates reported in our study and in other studies reporting on IPFF in patients undergoing HA for FNF.[19,20] We suggest that when operating on patients with FNF who are 95 years of age and older, surgeons should consider methods to mitigate the risk of PPF such as the use of cemented[11,12,19,25] and collared[26] stems.

A higher patient BMI was demonstrated to be a protective factor against IPFF. This observation could potentially be attributed to the well-documented association between higher BMI and higher bone mineral content at the femoral neck.[27] Nevertheless, studies assessing the direct impact of BMI on IPFF risk are scarce, and further research is needed to validate these findings. Interestingly, patient bone quality, as assessed by the Dorr classification, was not independently associated with IPFF risk. This contradicts a previous retrospective study by Hong et al.,[19] which reported on 271 patients who underwent BHA for FMF and showed that Dorr type C femurs are an independent risk factor for IPFF. Furthermore, the findings of our study showed that patient comorbidity burden, as measured by the ASA and CCI scores, was not associated with an increased risk of IPFF, which is consistent with previous reports by Hong et al.[19] and Bellova et al.[20] However, it is essential to note that further research is warranted to better understand the complex relationship between patient factors, bone quality, and the risk of IPFF.

The findings of this current study show that while older age was associated with increased rates of IPFF, it did not affect the pattern of the fracture. The majority of the patients in our cohort had an IPFF involving either the calcar or the great trochanter, regardless of the age group. This is corroborated by Abdel et al.[7] who reported that 69% of IPFF involve the calcar region and by Hong et al.[19] who reported the GT as the most common fracture site. As the treatment for IPFF is derived from the location of the fracture,[28] the treatment in our cohort was also similar across the age groups, and the treatment for most patients included cerclage wire fixation. Such findings may suggest that while the mechanism of injury is similar across the age groups, the poorer bone quality of the older patients, as represented by higher rates of patients with type C Dorr femurs, made them more susceptible to an IPFF. Abdel et al.[7] previously reported on the mechanism of IPFF injury and showed that it occurs mainly during preparation of the femoral canal, impaction of the femoral stem, or forceful repositioning of the implanted stem. In older patients, particularly those 95 years of age or older, extra care must be taken to minimize the risk of an IPFF.

IPFF can result in considerable morbidity and dysfunction for patients,[7] as well as an increase in healthcare costs and resource utilization.[29] Both can be attributed to the potential need for additional surgical interventions, prolonged hospital stays, and extended recovery periods. While there are limited data regarding functional outcomes following this type of injury, it is generally accepted that these fractures can lead to compromised functional outcomes, including pain, limited mobility, and reduced quality of life for affected individuals.[30] In this study, evaluating the differences in clinical outcomes between the age groups was challenging, especially when considering the increased rates of comorbidities in patients over 95 years old, represented by both the higher mean CCI and the increased rates of patients with ASA scores of 3 and 4. However, the similar postoperative weight-bearing status, as well as the comparable rates of orthopedic-related readmissions and revisions at the latest follow-up, suggests that the clinical outcomes of IPFF are not associated with the age of the patient. Nevertheless, the potential added morbidity and the increased burden on healthcare resources further emphasize the importance of preventive measures and meticulous surgical techniques to reduce the occurrence of IPFF and improve patient outcomes.

This includes acknowledging potential risk factors, such as the patient's age, followed by techniques aimed at minimizing IPFF risk, such as the use of cemented[11,12,19,25] and collared[26] stems, as well as the inclusion of experienced surgeons in the surgical team.[20]

Young et al.[5] have previously proposed that identification of the fracture at the time of surgery and appropriate steps taken to stabilize it are the most important factors to impact the outcomes. Having the majority of patients across the age groups treated with a cerclage wire fixation suggests that IPFF was identified and treated in most patients. Moreover, cerclage wire fixation was previously reported to result in similar functional outcomes when compared to patients without IPFF,[31] which may explain the similar outcomes across the age groups.

This study should be interpreted in light of its limitations. Due to its retrospective design, the inherent selection bias and bias due to loss to follow-up may have occurred. Additionally, due to the study design, we were unable to control for baseline patient characteristics, as older patients had significantly more comorbidities and thus were more prone to postoperative complications and mortality. Importantly, however, we were able to partially control these differences by reporting orthopedic-related complications separately. Moreover, although surgeon experience may influence the risk of IPFF, especially when using a cementless implant in osteoporotic patients,[32] we were unable to address this aspect in our study due to our institution's policy. We also acknowledge that other surgery-related factors may have impacted our results. However, in this study, our aim was to focus on patient characteristics as they can guide surgeons in surgical decision-making. Nonetheless, to account for some previously reported surgeon and surgery-related risk factors, we included only patients who underwent surgery via the anterolateral approach and those who received a cementless stem. Furthermore, the minimum follow-up period of 12 months may not be long enough to assess the long-term outcomes and complications of the procedure. However, it has been previously reported that the increased risk for a revision surgery following an IPFF is within the first 6 postoperative months.[8]

The findings of this study suggest that age over 95 years is a significant, independent risk factor for IPFF in patients undergoing cementless HA for FNF. Although we were unable to show an impact on perioperative outcomes and orthopedic complications, when operating on patients over 95 years of age, surgeons should be mindful of the increased risk of IPFF and consider strategies to mitigate this risk including the use of collared and cemented stems.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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