



The effect of steroid injection into the shoulder on glycemia in patients with type 2 diabetes



Ori Safran, MD^{a,*}, Gabriel Fraind-Maya, MD^a, Leonid Kandel, MD^a, Gil Leibowitz, MD^b, Shaul Beyth, MD, PHD^a

^aOrthopedic Department, The Hebrew University-Hadassah Medical School, Jerusalem, Israel

^bDiabetes Unit and Endocrine Service, The Hebrew University-Hadassah Medical School, Jerusalem, Israel

ARTICLE INFO

Keywords:

Shoulder
Diabetes mellitus
Corticosteroids
Injection
Hyperglycemia
Treatment

Level of evidence: Level II; Prospective Cohort Design; Treatment Study

Background: Injections of corticosteroids into or around joints have been reported to increase blood glucose in patients with diabetes due to corticosteroid absorption into the bloodstream. However, the magnitude, duration, and clinical implications of local corticosteroid injections on glycemic control are not clear. The purpose of this study was to evaluate the effects of corticosteroid injection to the shoulder on glycemia in patients with type 2 diabetes mellitus using a continuous glucose monitoring device.

Methods: Twenty-five patients with symptomatic shoulder problems and type 2 diabetes mellitus, not treated with insulin, prescribed a corticosteroid injection into the shoulder, were investigated. The patients were connected to a flash glucose monitoring system, which continuously monitored interstitial glucose levels. Data were collected 3 days before injection and for additional 11 days after corticosteroid injection. We analyzed glucose levels in the first 3 days (early postinjection) and on days 4–11 (late postinjection) after the injection and compared them to the preinjection period. The outcome measures included change in the average glucose levels, per patient, between the preinjection and postinjection periods and the differences in the time spent at glucose >180 mg/dL, >250 mg/dL, and >350 mg/dL, per patient, between the preinjection and postinjection periods.

Results: The increase in the mean glucose level per patient was statistically significant from 136 mg/dL in the preinjection period to 159 mg/dL in the first 3 days after the injection and returned to normal thereafter. Time at blood glucose >250 mg/dL increased from 4.3% in the preinjection period to 9.5% on the first day after the injection. It then decreased to 7% on day 2, 3.8% on day 3, and 1.4% in the late postinjection period. New onset of glucose levels >350 mg/dL was found in 4 of 25 patients during the early postinjection period. In all 4 patients, the exposure to severe hyperglycemia (>350 mg/dL) was short. None of the patients required intensification of the antidiabetic treatment or insulin injections.

Conclusion: Local corticosteroid injection to the shoulder can create a significant, short-term increase in systemic glucose levels in patients with D2DM not treated with insulin. Some of these patients may have periods with glucose above 350 mg %. However, these glycemic changes are short lived and are mostly limited to the 2–3 days after the injection. In addition, none of the patients in our study needed any change in antidiabetic treatment or any medical care after the injection.

© 2022 The Author(s). Published by Elsevier Inc. on behalf of American Shoulder and Elbow Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Type 2 diabetes mellitus (T2DM) is a global epidemic affecting 13% of the US adult population (34.1 million), with 1.5 million Americans newly diagnosed with diabetes annually.

Diabetes is associated with musculoskeletal pathologies, including osteoarthritis and impaired tendon homeostasis and

healing.²¹ In the shoulder, diabetes is mainly associated with rotator cuff pathology^{1,18} and adhesive capsulitis.^{14,24} These painful conditions can be disabling and impede these patients' ability to perform routine physical activity.

Local corticosteroid injections are often used as part of the conservative management of many painful shoulder conditions. These include rotator cuff disorders, biceps pathology, osteoarthritis, and frozen shoulder.^{5,19,28} Local corticosteroid injections are aimed to relieve pain, reduce inflammation, and improve mobility with the advantages of ease of delivery, low cost, and relatively low risk for the patient.⁵

The Committee on research involving human subjects of the Hebrew University Hadassah Medical School approved this study—0261-17-HMO.

*Corresponding author: Ori Safran, MD, Kiryat Hadassah 12000 POB 12000, Jerusalem 91200.

E-mail address: oris@hadassah.org.il (O. Safran).

<https://doi.org/10.1016/j.jseint.2022.05.016>

2666-6383/© 2022 The Author(s). Published by Elsevier Inc. on behalf of American Shoulder and Elbow Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Systemic administration of corticosteroids is often associated with increased blood glucose levels.^{5,12} Local injections of corticosteroids into or around joints and tendons have also been reported to increase blood glucose in T2DM patients due to partial corticosteroid absorption to the bloodstream.^{5,12,30} The literature contains only a few prospective studies, with a small number of participants, assessing the effect of local corticosteroid injection to the shoulder on glycemia.^{2,13,20,26,29,30} These studies have shown a mild increase in average blood glucose levels after shoulder intra-articular corticosteroid injections.^{2,13,20,26,29,30} However, all these studies used a small number of glucose measurements carried out in each patient, which does not necessarily represent the patient's glucose levels after the injection. None of these studies analyzed the effects of injected local corticosteroids continuously throughout the study period.

Herein, we aimed to perform an in-depth analysis of the short-term effects of corticosteroid injection to the shoulder on glycemia in patients with T2DM using a continuous glucose monitoring device. We hypothesized that the patient's glucose levels would increase in the first 3 days after the injection and return to baseline thereafter.

Material and methods

Study design and participants

The local ethics committee approved this study. All patients provided written informed consent. Eligible participants were patients aged >35 years attending our shoulder clinic with symptomatic shoulder problems and T2DM and prescribed by a board-certified shoulder specialist to have a corticosteroid injection into the shoulder. We included patients treated for T2DM with oral medications and/or glucagon-like peptide one receptor agonists. The antidiabetic medical regimen had to be stable over the last 3 months before inclusion. We excluded patients treated with insulin injections. The reason for that was the ability of the patients to easily change the insulin dosage in response to the changing glucose levels, which may interfere with data analysis. As most T2DM do not use insulin injection, we assumed that our results will still represent most T2DM patients. Other exclusion criteria were hospitalization due to hypo/hyperglycemia over the previous 6 months, corticosteroid injections during the last 3 months, and systemic use of corticosteroids.

Glucose monitoring

Flash glucose monitoring system FreeStyle Libre (Abbott Diabetes Care, Alameda, CA, USA) monitors subcutaneous interstitial glucose levels in diabetic patients. It is commonly used to assess glycemic control in patients with type 1 diabetes mellitus (T1DM) and T2DM.^{7,9,17}

This tool includes a reader device and a small disposable sensor, applied on the upper arm's back for up to 14 days, according to the manufacturer's directions. It is factory calibrated and has no automatic alarms. The sensor measures glucose levels continuously. These data are automatically stored on the sensor and uploaded to the reader when brought into the sensor's proximity. For a complete 24-hour glycemic profile, data transfer from the sensor to the reader is performed at least once every 8 hours. Using the device software, we can generate a summary glucose report. According to the literature, there might be an average difference of 10% in glucose measurements between glucose readings using FreeStyle Libre and glucose blood measurements in the hyperglycemic range.^{3,17,27,31}

After receiving informed consent, we attached the FreeStyle Libre sensor to the patients and guided them on how to use the device. We asked the participants to return 3 days later to receive the corticosteroid injection. As a single sensor collects data for 14 days, we had glucose monitoring data 3 days before the injection and 11 days afterward. After completing the monitoring period, patients removed the sensor, and the data were transferred from the FreeStyle Libre device to the study computer.

Injection and medication

A board-certified shoulder surgeon administered each injection without any additional imaging. As most steroid injections to the shoulder are done in the outpatient clinic without an additional imaging modality, we aimed to simulate the current practice of shoulder steroid injections. Injected material included 40 mg of methylprednisolone acetate in all patients (1 cc of 40 mg/mL), mixed with 1% lidocaine. The total volume of the injection to the subacromial space, glenohumeral joint, biceps tendon, and acromioclavicular joint (ACJ) was 8 cc, 8 cc, 5 cc, and 2 cc, respectively. The subacromial space was approached posteriorly, the glenohumeral space was approached anteriorly, and the ACJ was approached superiorly. Injection to the biceps tendon was targeted to the point of maximum tenderness along the long head of the biceps. Each patient received only one injection in this study. We used methylprednisolone acetate for the corticosteroid because it is commonly used for joint injection.²⁸ Patients were asked to report any adverse effects to the study coordinators. After the injection, patients were given oral as well as written instructions to immediately call one of the investigators (O.S., S.B., and G.L.) in case they feel not well in any way during the study period.

Clinical data

All patients filled out a questionnaire regarding their demographics, medical history, including the age at diagnosis of diabetes, disease duration, and medical treatment. We recorded the patients' weight and height.

We drew blood for HbA_{1c} measurement before corticosteroid injection. However, we did not know the HbA_{1c} result before the injection, and it did not serve to include or exclude patients to this study.

Outcomes

Glucose level change after the injection can be evaluated using 2 main methods. The first is the change in the average glucose levels, per patient, between the preinjection and postinjection periods. Another method includes the change in time spent, per patient, at glucose levels above a selected threshold level between the preinjection and postinjection periods. The latter includes the summation of the number of measurements above the threshold level divided by the total number of measurements in each period.⁴ The latter is a more practical and appropriate method to follow and control patients' glycemic control.⁴ The threshold glucose levels recommended for the evaluation of diabetes control by the International Consensus on Time in Range are time above 180 mg/dL and 250mg/dL. We have used these thresholds and an additional threshold of 350 mg/dL to evaluate periods with extreme hyperglycemia.

We have decided to use both evaluation methods in this study to better assess the glucose changes after the corticosteroid injection.

Our primary endpoint was the change in the average glucose levels, per patient, between the preinjection and postinjection periods. Our secondary endpoints were the differences in the time

Table I
Percentage of time spent in different glucose categories for each patient during the different study periods.

Patient	Before injection				1-3 days after injection				≥4 days after injection				HbA _{1c}
	<180	180-250	251-350	>350	<180	180-250	251-350	>350	<180	180-250	251-350	>350	
1	92.0%	8.0%	0.0%	0.0%	91.2%	8.8%	0.0%	0.0%	95.9%	4.0%	0.1%	0.0%	6.6
2	96.3%	3.7%	0.0%	0.0%	93.5%	6.5%	0.0%	0.0%	97.9%	2.1%	0.0%	0.0%	6.4
3	78.1%	16.9%	2.8%	2.2%	66.1%	31.4%	2.5%	0.0%	83.6%	14.8%	1.6%	0.0%	7.9
4	39.9%	59.0%	1.1%	0.0%	40.6%	55.8%	3.6%	0.0%	48.2%	46.4%	5.4%	0.0%	8.2
5	74.2%	24.7%	1.1%	0.0%	62.4%	22.5%	15.1%	0.0%	93.9%	6.1%	0.0%	0.0%	7.8
6	97.4%	2.6%	0.0%	0.0%	91.5%	5.9%	2.6%	0.0%	98.3%	1.7%	0.0%	0.0%	6.4
7	1.7%	30.1%	55.4%	12.7%	18.1%	33.3%	37.0%	11.6%	52.4%	46.2%	1.4%	0.0%	9.6
8	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	5.9
9	100.0%	0.0%	0.0%	0.0%	95.4%	4.6%	0.0%	0.0%	89.1%	10.8%	0.1%	0.0%	6.8
10	95.6%	4.4%	0.0%	0.0%	33.2%	62.6%	4.2%	0.0%	86.4%	13.6%	0.0%	0.0%	6.4
11	99.7%	0.3%	0.0%	0.0%	89.9%	10.1%	0.0%	0.0%	99.0%	1.0%	0.0%	0.0%	5.8
12	99.7%	0.3%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	5.9
13	99.0%	1.0%	0.0%	0.0%	92.0%	8.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	6.4
14	77.8%	17.9%	4.3%	0.0%	63.8%	24.2%	11.1%	1.0%	71.4%	20.7%	7.5%	0.3%	7.4
15	46.1%	44.3%	9.6%	0.0%	12.0%	53.0%	32.2%	2.8%	51.1%	47.5%	1.4%	0.0%	8.7
16	87.5%	12.5%	0.0%	0.0%	92.9%	7.1%	0.0%	0.0%	91.1%	8.9%	0.0%	0.0%	7.5
17	60.8%	38.5%	0.7%	0.0%	47.9%	52.1%	0.0%	0.0%	93.3%	6.7%	0.0%	0.0%	7.4
18	51.0%	35.9%	13.1%	0.0%	44.1%	35.0%	19.9%	1.0%	39.1%	53.1%	7.8%	0.0%	9.6
19	95.8%	4.2%	0.0%	0.0%	95.2%	4.8%	0.0%	0.0%	97.6%	2.4%	0.0%	0.0%	7.6
20	98.7%	1.3%	0.0%	0.0%	92.9%	7.1%	0.0%	0.0%	90.2%	9.6%	0.3%	0.0%	7.7
21	94.6%	5.4%	0.0%	0.0%	98.3%	1.7%	0.0%	0.0%	99.7%	0.3%	0.0%	0.0%	7.7
22	82.4%	15.3%	2.3%	0.0%	74.3%	25.1%	0.7%	0.0%	93.5%	6.5%	0.0%	0.0%	8.1
23	89.2%	10.8%	0.0%	0.0%	90.9%	6.9%	2.2%	0.0%	95.6%	4.4%	0.0%	0.0%	7.8
24	75.0%	22.5%	2.5%	0.0%	58.0%	27.2%	13.0%	1.8%	62.4%	30.3%	7.2%	0.1%	6.8
25	99.0%	1.0%	0.0%	0.0%	99.2%	0.8%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	6.3
Mean	81.3%	14.4%	3.7%	0.6%	73.7%	19.8%	5.8%	0.7%	85.2%	13.5%	1.3%	0.02%	7.3
SD	23.9%	15.9%	11.0%	2.5%	26.8%	19.0%	10.1%	2.3%	18.7%	16.8%	2.5%	0.1%	1.0

SD, standard deviation.

spent at glucose >180 mg/dL, >250 mg/dL, and >350 mg/dL, per patient, between the preinjection and postinjection periods.

Statistical analysis

Sample size analysis showed that a sample size of 22 patients was needed for an 80% power to reject the null hypothesis of equal means with a mean difference of 30.0 mg/dL in change from glucose levels before the injection to that in the days after the injection and a common standard deviation of 30 at an alpha level of 0.05. The mean difference and standard deviation are based on and similar to those used in previous studies.^{25,29}

The glycemic changes were analyzed per day after the injection and were also grouped into 3 periods: preinjection (3 days before injection), early postinjection period (days 1-3 after the injection), and late postinjection period days 4-11 after the injection. This is based on the previous studies that showed more prominent glycemic changes in the first 3 days after the steroid injection.^{12,25,26}

The change in the average glucose levels, per patient, between the preinjection and postinjection periods and a comparison between periods was performed using a *t*-test. Percent of time spent at glucose >180, 250, and 350 mg/dL were calculated at preinjection and postinjection periods for each patient. The changes between periods per patient were analyzed using a paired *t*-test. All analyses were performed using R 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

We recruited 26 patients; one patient had his sensor fall off a day after the injection, so he remained without glucose readings for 48 hours. He was, therefore, excluded from the study. Of the remaining 25 patients who completed the trial, 17 were males (68%), and 8 were females (32%). The mean age was 65 ± 9 years (range 50-83), body mass index was 28.6 ± 4.1 kg/m² (range 21.5-

36.4), and Hb A_{1c} was 7.3 ± 1 (range 5.8-9.6). Patients' diagnoses included rotator cuff tear in 18 patients, adhesive capsulitis in 3 patients, long head of biceps tendinosis in 2 patients, calcified tendinosis on 1 patient, and ACJ arthrosis in 1 patient. In 19 patients, the injection was targeted to subacromial space (76%), 3 to the glenohumeral joint (12%), 2 to the long head of the biceps (8%), and 1 patient to the ACJ (4%).

Change in average glucose

The mean glucose level, per patient, increased from 136 mg/dL before injection to 159 mg/dL on postinjection day 1 (*P* < .0001) and 154 mg/dL on postinjection day 2 (*P* < .0001 compared with the preinjection period). It then decreased to 140 mg/dL on postinjection day 3 (*P* = .2650 compared with the preinjection period) and 135 mg/dL in the 4-11 days (late postinjection period) after the injection. The mean glucose level in the late postinjection period was not significantly different from that in the preinjection period (*P* = .2358).

Time above the glucose target range

We measured the percentage of time in which patients' glucose levels were ≤180 mg/dL, >180 to 250 mg/dL, >250 to 350 mg/dL, and >350 mg/dL. The individual's percentages of time spent in different glucose categories during the different study periods are shown in Table I. The data for the entire study group are presented in Figure 1.

There was a statistically significant increase in the percentage of time with glucose levels >180 mg/dL, per patient, from 19% before injection to 29.6% and 29.8% on postinjection days 1 and 2, respectively (*P* = .0067, *P* = .0044 compared with the preinjection period). It then decreased to 21.2% on day 3 (*P* = .5685 compared with the preinjection period) and 15.2% in the late postinjection period (*P* = .1884 compared with the preinjection period).

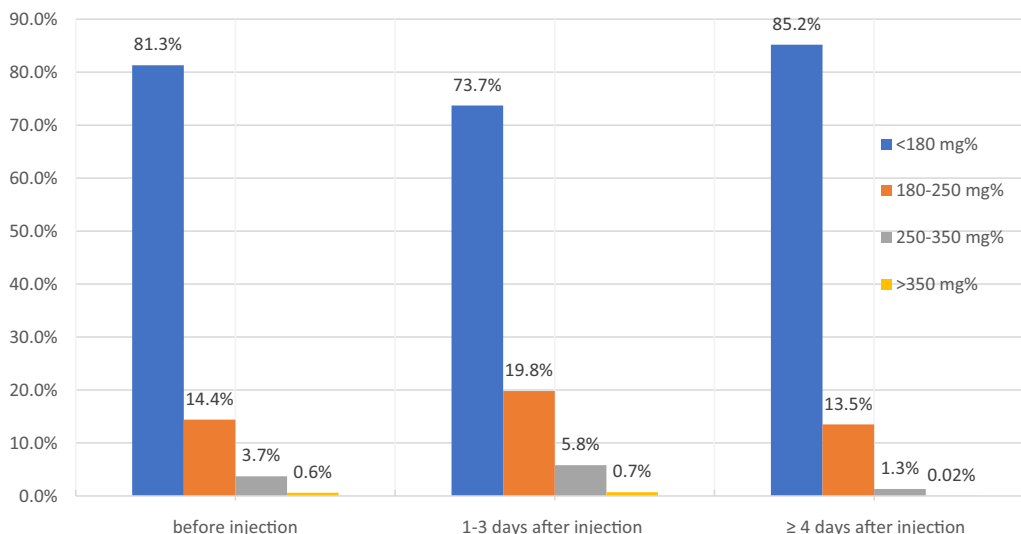


Figure 1 The percentage of time spent in different glucose categories (time in range) before injection and during the early and late postinjection periods. Glucose categories: ≤ 180 mg/dL, >180 -250 mg/dL, >250 -350 mg/dL, and >350 mg/dL.

There was a statistically significant increase in the percentage of time with glucose levels >250 mg/dL, per patient, from 4.3% before injection to 9.5% on day 1 postinjection ($P = .0278$). It then gradually decreased to 7% on postinjection day 2 ($P = .1743$ compared with the preinjection period), 3.8% on postinjection day 3 ($P = .8511$ compared with the preinjection period), and to 1.4% in the late postinjection period (days 4-11; $P = .27$).

The percentage of time in which glucose levels were >350 mg/dL was 0.6% before injection, 1.1% on postinjection day 1, 1.0% on postinjection day 2, and 0.02% on day 3, and the late postinjection period (days 4-11). These differences were not statistically significant.

Specifically, there were 5 patients (20%) with glucose measurements >350 mg/dL during the early postinjection period (days 1-3 after the injection). One of these patients, with an HbA_{1c} of 9.6%, had 12.7% of measurements with glucose >350 mg/dL in the preinjection period. It decreased to 11.6% in the early postinjection period. In the late postinjection period, no measurements >350 mg/dL were recorded in this patient. The other 4 patients had new-onset glucose levels >350 mg/dL in the early postinjection period. The first patient, a 68-year-old man with an HbA_{1c} of 6.8%, had 1.8% of glucose level readings above 350 mg/dL in the early postinjection period, which decreased to 0.1% in the late postinjection period. The second, a 71-year-old patient with an HbA_{1c} of 7.4%, had 1% of glucose level readings above 350 mg/dL in the early postinjection period, which decreased to 0.3% in the late postinjection period. The third, a 57-year-old man with an HbA_{1c} of 8.7%, had 2.8% of glucose level readings above 350 mg/dL in the early postinjection period, which decreased to 0% in the late postinjection period. The fourth patient, a 61-year-old man with a HbA_{1c} of 9.6%, had 1.0% of glucose level readings above 350 mg/dL in the early postinjection period, which decreased to 0% in the late postinjection period.

Hb A_{1c} and time above the glucose target range

We compared the percentage time spent above 250 mg/dL in patients with $HbA_{1c} >7.5$ (11 patients) to those with $HbA_{1c} \leq 7.5$ (14 patients). The cutoff of 7.5% is based on the American College of Physicians guidance statement from 2018,²³ which stated that clinicians should aim to achieve an HbA_{1c} level between 7% and 8% in

most patients with type 2 diabetes. Therefore, we used a midpoint of this range to differentiate between controlled and uncontrolled diabetic patients. Patients with $HbA_{1c} >7.5$ had significantly higher percentage of time >250 mg/dL in the preinjection period (9.1% vs. 0.5%; $P = .038$), early postinjection period (11.7% vs. 2.4%; $P = .01$) but not in the late postinjection period (1.6% vs. 1.1%; $P = .508$).

Clinical follow-up

None of the 25 patients reported any adverse effects related to the injection or any change with their antihyperglycemic treatment after the injection. None of the patients needed any medical care for symptomatic hyperglycemia during the study period.

Discussion

In this study, we investigated the effects of corticosteroid injection into the shoulder on patients with T2DM not treated with insulin. This group of patients represents most diabetic patients.⁸ We found a significant increase in systemic glucose levels in the first 3 days after a glucocorticoid injection into the shoulder. This increase was short lived, with a return of glucose levels toward baseline in the following days.

The increase in the mean glucose level, per patient, was relatively mild from 136 mg/dL in the preinjection period to 159 mg/dL in the first 3 days after the injection and returned to normal thereafter. These findings are consistent with the previous small case series showing a mild increase in mean blood glucose levels after shoulder intra-articular corticosteroid injections.^{2,13,20,26,29,30}

Using continuous monitoring of glucose levels in this study, we assessed the percentage of time patients' glucose levels were in the hyperglycemic regions before and after the injection. The continuous monitoring allowed us to perform a more accurate and comprehensive evaluation of the impact of corticosteroid injection on glycemia and the degree of exposure to severe hyperglycemia. To our knowledge, this is the first study to use continuous glucose monitoring technology to study the effects of corticosteroid injection to the shoulder on glycemia in patients with T2DM.

We found a 2-fold increase in the time patients were exposed to significant hyperglycemia (glucose levels above 250 mg/dL) on day

1 after the injection. It increased, per patient, from 4.3% before the injection to 9.5% on the day after injection. However, this rise was short, returning to the preinjection state on day 3 after the injection.

One of the concerns when injecting corticosteroids to type II diabetic patients is a hyperosmolar nonketotic state, with extreme hyperglycemia, dehydration, and electrolyte disturbance requiring emergency treatment and hospitalization. Therefore, we were interested in patients with severe hyperglycemia, that is, glucose levels exceeding 350 mg/dL, after the steroid injection. Four patients (16%) had a new onset of blood glucose >350 mg/dL in the early postinjection period. The exposure to severe hyperglycemia (>350 mg/dL) was short (1%–2.8% of all measurements during the early postinjection period). Two patients continued to have glucose measurements >350 mg/dL during the late postinjection period but for very periods (0.1%–0.3% of all measurements). None of these patients required intensification of the antidiabetic treatment or an additional medical treatment.

We found that patients with T2DM, who are less well controlled (HbA_{1c} >7.5%), spent more time with significant hyperglycemia (>250 mg/dL) in both the preinjection as well as the early postinjection periods, but not in the late postinjection period (≥ 4 days). Similar results have also been shown in previous studies.^{2,26,29,30} However, 2 of the 4 patients with a new onset of severe hyperglycemic levels after the injection (>350 mg/dL) had baseline HbA_{1c} levels of 7.4% and 6.8%. Therefore, severe hyperglycemia can also occur in patients with moderately controlled T2DM and relatively lower HbA_{1c}.

None of the patients reported any change with their anti-hyperglycemic treatment or needed medical care for symptomatic hyperglycemia during the study period. This is similar to other studies, which reported no adverse clinical effects of hyperglycemia after a steroid injection to the shoulder in T2DM.^{5,30} It seems that although corticosteroid injection to the shoulder may create significant glucose level elevations in T2DM patients, the return to preinjection glucose level is fast, and the patients do not suffer any obvious immediate clinical side effects related to the glucose level change.

Different steroids and dosages may change the extent of glucose level excursions and the durability of dysglycemia.^{5,16,25} We could find reports of hyperglycemia after a musculoskeletal steroid injection with the use of methylprednisolone, triamcinolone, betamethasone, and celestone.⁵ However, we could not find any good quality study comparing the glycemic effects of different corticosteroids or different dosages of corticosteroids injected to or around joints. We have used 40 mg of methylprednisolone in this study because it is commonly used for injections to the shoulder and other musculoskeletal sites.^{10,19,28}

The effect of steroid injection in T1DM may differ from that in patients with T2DM.^{11,22} Patients with T1DM, which are not part of this study, have been reported to develop significant hyperglycemia that lasts longer after a steroid injection.^{2,22,30} Therefore, our data should not be automatically extrapolated to T1DM, and further study targeted at these patients is needed. In addition, patients with T2DM treated with insulin were not included in this study because of their ability to easily change the insulin dosage in response to the changing glucose levels. Nevertheless, this study relates to most diabetic patients because it focused on T2DM patients not treated with insulin, which are the vast majority of diabetic patients, especially those in need of corticosteroid injections.⁸

This study has several limitations. The study group is small. Although larger than in prior studies, it involves 25 patients with a small number of injections into locations outside of the subacromial space. The study lacks a control group of diabetic patients

connected to FreeStyle Libre without local injection of corticosteroids. The use of continuous glucose monitoring may affect glycaemic control, as the patient is aware of blood glucose levels and may better adhere to diet and medical treatment. However, connecting the continuous glucose monitoring device to the patients a few days before the injection gives us the patient's baseline glucose control before the injection itself. Therefore, it may serve as the patient's self-control to the effects of the injection itself. There is also no control group of nondiabetic patients receiving the same cortisone injections. This control group would allow further comparison to evaluate whether the postinjection increase in blood glucose levels in nondiabetic patients is any different than in T2DM patients not on insulin. The injections were not directed by imaging. Therefore, they may have shifted in some cases from the intended injection target, as shown in previous studies.^{6,15} However, most steroid injections to the shoulder are done in the outpatient clinic without an additional imaging modality. Our study, therefore, simulates the current practice of shoulder steroid injection. Finally, the duration of follow-up after injection was 11 days after the injection. The long-term effects on glycaemic control have not been evaluated. Nevertheless, the fact that corticosteroid injections had short-lived effects on glycaemia may argue against significant long-term effects.

Conclusion

Our findings show that local corticosteroid injection to the shoulder can create a significant, short-term increase in systemic glucose levels in patients with D2DM, not treated with insulin. Some of these patients may have short periods with glucose above 350 mg%, even in those with HbA_{1c} lower than 7%. However, it seems that the likelihood of clinical side effects is low.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Abate M, Schiavone C, Salini V, Andia I. Occurrence of tendon pathologies in metabolic disorders. *Rheumatology (Oxford)* 2013;52:599–608. <https://doi.org/10.1093/rheumatology/kes395>.
2. Aleem AW, Syed UAM, Nicholson T, Getz CL, Namdari S, Beredjikian PK, et al. Blood glucose levels in diabetic patients following corticosteroid injections into the subacromial space of the shoulder. *Arch Bone Jt Surg* 2017;5:315–21.
3. Bailey T, Bode BW, Christiansen MP, Klaff LJ, Alva S. The performance and usability of a factory-calibrated flash glucose monitoring system. *Diabetes Technol Ther* 2015;17:787–94. <https://doi.org/10.1089/dia.2014.0378>.
4. Battelino T, Danne T, Bergenstal RM, Amiel SA, Beck R, Biester T, et al. Clinical targets for continuous glucose monitoring data interpretation: recommendations from the international consensus on time in range. *Diabetes Care* 2019;42:1593–603. <https://doi.org/10.2337/dci19-0028>.
5. Choudhry MN, Malik RA, Charalambous CP. Blood glucose levels following intra-articular steroid injections in patients with diabetes: a systematic review. *JBJs Rev* 2016;4:e5. <https://doi.org/10.2106/JBJs.RVW.O.00029>.
6. Daley EL, Bajaj S, Bisson LJ, Cole BJ. Improving injection accuracy of the elbow, knee, and shoulder: does injection site and imaging make a difference? A systematic review. *Am J Sports Med* 2011;39:656–62. <https://doi.org/10.1177/0363546510390610>.
7. Deshmukh H, Wilmot EG, Gregory R, Barnes D, Narendran P, Saunders S, et al. Effect of flash glucose monitoring on glycaemic control, hypoglycaemia, diabetes-related distress, and resource utilization in the Association of British Clinical Diabetologists (ABCD) Nationwide Audit. *Diabetes Care* 2020;43:2153–60. <https://doi.org/10.2337/dc20-0738>.
8. Federation ID. *IDF diabetes Atlas. 10th ed. Brussels, Belgium: International Diabetes Federation; 2021.*

9. Fokkert M, van Dijk P, Edens M, Barents E, Mollema J, Slingerland R, et al. Improved well-being and decreased disease burden after 1-year use of flash glucose monitoring (FLARE-NL4). *BMJ Open Diabetes Res Care* 2019;7:e000809. <https://doi.org/10.1136/bmjdr-2019-000809>.
10. Garg N, Perry L, Deodhar A. Intra-articular and soft tissue injections, a systematic review of relative efficacy of various corticosteroids. *Clin Rheumatol* 2014;33:1695-706. <https://doi.org/10.1007/s10067-014-2572-8>.
11. Gonzalez P, Laker SR, Sullivan W, Harwood JE, Akuthota V. The effects of epidural betamethasone on blood glucose in patients with diabetes mellitus. *PM R* 2009;1:340-5. <https://doi.org/10.1016/j.pmrj.2008.12.007>.
12. Habib GS. Systemic effects of intra-articular corticosteroids. *Clin Rheumatol* 2009;28:749-56. <https://doi.org/10.1007/s10067-009-1135-x>.
13. Habib GS, Abu-Ahmad R. Lack of effect of corticosteroid injection at the shoulder joint on blood glucose levels in diabetic patients. *Clin Rheumatol* 2007;26:566-8. <https://doi.org/10.1007/s10067-006-0353-8>.
14. Hsu JE, Anakwenze OA, Warrender WJ, Abboud JA. Current review of adhesive capsulitis. *J Shoulder Elbow Surg* 2011;20:502-14. <https://doi.org/10.1016/j.jse.2010.08.023>.
15. Kang MN, Rizio L, Prybicien M, Middlemas DA, Blacksin MF. The accuracy of subacromial corticosteroid injections: a comparison of multiple methods. *J Shoulder Elbow Surg* 2008;17(1 Suppl):61S-6S. <https://doi.org/10.1016/j.jse.2007.07.010>.
16. Kim WH, Sim WS, Shin BS, Lee CJ, Jin HS, Lee JY, et al. Effects of two different doses of epidural steroid on blood glucose levels and pain control in patients with diabetes mellitus. *Pain Physician* 2013;16:557-68.
17. Leelarathna L, Wilmot EG. Flash forward: a review of flash glucose monitoring. *Diabet Med* 2018;35:472-82. <https://doi.org/10.1111/dme.13584>.
18. Leong HT, Fu SC, He X, Oh JH, Yamamoto N, Hang S. Risk factors for rotator cuff tendinopathy: a systematic review and meta-analysis. *J Rehabil Med* 2019;51:627-37. <https://doi.org/10.2340/16501977-2598>.
19. Martin CL, Browne JA. Intra-articular corticosteroid injections for symptomatic knee osteoarthritis: what the orthopaedic provider needs to know. *J Am Acad Orthop Surg* 2019;27:e758-66. <https://doi.org/10.5435/JAAOS-D-18-00106>.
20. Moon HJ, Choi KH, Lee SI, Lee OJ, Shin JW, Kim TW. Changes in blood glucose and cortisol levels after epidural or shoulder intra-articular glucocorticoid injections in diabetic or nondiabetic patients. *Am J Phys Med Rehabil* 2014;93:372-8. <https://doi.org/10.1097/PHM.0000000000000001>.
21. Nichols AEC, Oh I, Loiselle AE. Effects of type II diabetes mellitus on tendon homeostasis and healing. *J Orthop Res* 2020;38:13-22. <https://doi.org/10.1002/jor.24388>.
22. Povlsen B, Povlsen SD. Steroid injection for shoulder pain causes prolonged increased glucose level in type 1 diabetics. *BMJ Case Rep* 2014;2014:bcr2014203777. <https://doi.org/10.1136/bcr-2014-203777>.
23. Qaseem A, Wilt TJ, Kansagara D, Horwath C, Barry MJ, Forciea MA, et al. Hemoglobin A1c targets for glycemic control with Pharmacologic Therapy for Nonpregnant adults with type 2 diabetes mellitus: a guidance statement Update from the American College of Physicians. *Ann Intern Med* 2018;168:569-76. <https://doi.org/10.7326/M17-0939>.
24. Redler LH, Dennis ER. Treatment of adhesive capsulitis of the shoulder. *J Am Acad Orthop Surg* 2019;27:e544-54. <https://doi.org/10.5435/JAAOS-D-17-00606>.
25. Russell SJ, Sala R, Conaghan PG, Habib G, Vo Q, Manning R, et al. Triamcinolone acetonide extended-release in patients with osteoarthritis and type 2 diabetes: a randomized, phase 2 study. *Rheumatology (Oxford)* 2018;57:2235-41. <https://doi.org/10.1093/rheumatology/key265>.
26. Shin WY, An MJ, Im NG, Oh KR, Choe Y, Yoon SR, et al. Changes in blood glucose level after steroid injection for musculoskeletal pain in patients with diabetes. *Ann Rehabil Med* 2020;44:117-24. <https://doi.org/10.5535/arm.2020.44.2.117>.
27. Staal OM, Hansen HMU, Christiansen SC, Fougner AL, Carlsen SM, Stavdahl Ø. Differences between flash glucose monitor and fingerprick measurements. *Biosensors (Basel)* 2018;8:93. <https://doi.org/10.3390/bios8040093>.
28. Stephens MB, Beutler AI, O'Connor FG. Musculoskeletal injections: a review of the evidence. *Am Fam Physician* 2008;78:971-6.
29. Twu J, Patel N, Wolf JM, Conti Mica M. Impact of variation of corticosteroid dose, injection site, and multiple injections on blood glucose measurement in diabetic patients. *J Hand Surg Am* 2018;43:738-44. <https://doi.org/10.1016/j.jhssa.2018.06.005>.
30. Waterbrook AL, Balcik BJ, Goshinska AJ. Blood glucose levels after local musculoskeletal steroid injections in patients with diabetes mellitus: a clinical review. *Sports Health* 2017;9:372-4. <https://doi.org/10.1177/1941738117702585>.
31. Yan R, Li H, Kong X, Zhai X, Chen M, Sun Y, et al. The accuracy and precision of the continuously stored data from flash glucose monitoring system in type 2 diabetes patients during standard meal tolerance test. *Int J Endocrinol* 2020;2020:5947680. <https://doi.org/10.1155/2020/5947680>.