# Atrophy of the abdominal wall muscles after extraperitoneal approach to the aorta

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***Objective:*** **We retrospectively assessed computed tomography (CT) scans to determine degree of anterolateral abdominal muscle atrophy in patients who underwent infrarenal aortic repair with 2 kinds of incisions for the extraperitoneal approach.**

***Methods:*** **CT scans obtained before surgery and final scans obtained 2 to 100 months after surgery were assessed in 12 patients with paramedian incision (PM group) and 27 patients with flank incision (F group) who could be followed up at our hospital. We considered muscle thickness before surgery on the incision side to be 100% thickness (baseline value), and we calculated, by measuring the incision side after surgery, the corrected percent thickness (CPT%), which represents percentage of remaining muscle thickness that has escaped incision-induced atrophy. CT scans obtained at the level of the third (L3) and fifth (L5) lumbar vertebrae and the center of the sacrum (S) were selected for CPT% measurement.**

***Results:*** **Duration from surgery to final CT scan was 2 to 65 months (mean ± SD, 34.33 ± 21.38 months) in PM group and 3 to 96 months (27.85 ± 20.74 months) in F group. In PM group, mean CPT% values of the rectus abdominis muscle were 55.83 ± 21.65% at L3, 35.50 ± 10.79% at L5, and 31.92 ± 11.00% at S; these values were statistically much smaller than baseline ($P < .01$). Mean CPT% values of the lateral abdominal muscles were not statistically different from baseline. In F group, mean CPT% values of the rectus abdominis muscle were 82.19 ± 23.15% at L5 and 64.41 ± 31.34% at S; these values were statistically smaller than baseline ($P < .01$). Mean CPT% values of the lateral abdominal muscles were 87.59 ± 22.30% at L3 and 84.59 ± 26.90% at L5; these values were statistically smaller than baseline ($P < .05$).**

***Conclusions:*** **Paramedian incision induced severe rectus abdominis muscle atrophy. Although flank incision induced various degrees of atrophy in both muscles, some patients had no muscle atrophy. These data indicate that further anatomic investigation into the relation between flank incision and abdominal wall innervation may contribute to prevention of muscle atrophy after flank incision. (J Vasc Surg 2003;38:346-53.)**

Although various surgical approaches to the infrarenal abdominal aorta have been reported,[1-6] the midline transperitoneal approach is most widely used. The extraperitoneal approach has been reported by many authors to have physiologic advantages over those of the transperitoneal approach in reducing postoperative ileus and respiratory complications.[4-6] However, there is a relatively high incidence of long-lasting wound pain and abdominal bulge associated with the extraperitoneal approach.[7-9] These complications are thought to be caused mainly by nerve injury, but incision-related muscular injury and reduced blood supply may contribute in part to the complications.[8,10-13] Googman and Balachandran[14] reported atrophy of the abdominal muscles after various abdominal and thoracic operations. Hayashi et al[15] investigated the degree of denervated paravertebral muscle atrophy experimentally, and Mayer et al[16] investigated the degree of paravertebral muscle atrophy in patients who underwent spinal surgery. To our knowledge, however, there are no studies that examined the relation between type of incision used in repair of abdominal aortic disease and the resulting degree of abdominal muscle atrophy. Although we have used the midline transperitoneal approach, we have also used the extraperitoneal approach, because of its reported advantages, making use of both the paramedian and flank incision. We retrospectively assessed the degree of anterolateral abdominal muscle atrophy in patients who underwent infrarenal aortic aneurysm repair with either one of these incisions for the extraperitoneal approach. Assessment was made on the basis of findings on computed tomography (CT) scans.

## METHODS

### Study patients

Between January 1969 and December 2001, 351 patients underwent aortic reconstruction because of infrarenal aortic aneurysm at Showa University Hospital. The paramedian incision was used in 28 of these patients between 1987 and 1991, and the flank incision was used in 64 of these patients between 1991 and 2001, both for the extraperitoneal approach. Of these 92 patients, 12 patients with a paramedian incision (PM group) and 27 patients with a flank incision (F group) who could be followed-up at our hospital underwent CT within 3 months before surgery and again 2 to 100 months after surgery. These 39 patients are the subjects of the present study. The PM group comprised 12 men (age range, 51-79 years; mean, 66.2 years) who underwent CT after surgery 1 to 3 times each. The F group comprised 20 men and 7 women (age range, 59-89

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**Fig 1.** Measurement points on CT images. **A,** Thickness of rectus abdominis muscle and lateral abdominal muscles were determined at their thickest points. **B,** In F group patients in whom muscles atrophied medially from the incision (*arrowhead*), the thickest point of atrophied segments of lateral abdominal muscles was measured. **C,** Also in F group patients who exhibited atrophy of a broad area of the lateral abdominal muscles beyond the incision line, the thickest point was measured.

years; mean, 73.4 years) who underwent CT after surgery 1 to 4 times each. Operations were performed by several surgeons under the direction of two of the authors (M.Y. or T.T.).

### Operative procedures

**Paramedian incision.** A vertical incision is made approximately 6 cm to the left of midline, extending from the costal margin to just above the pubis. In a similar manner, the left anterior rectus sheath is incised at the external end of the rectus abdominis muscle, and the posterior rectus sheath is incised above the semilunar line. The extraperitoneal space is then entered for access to the aorta.

**Flank incision.** An oblique and slightly curved incision is made from the lateral margin of the left rectus sheath, beginning midway between the umbilicus and the symphysis pubis and extending laterally within the dermatome of the left eleventh intercostal nerve to the eleventh rib. After division of the skin and subcutaneous tissues, the lateral abdominal muscles, ie, the external oblique muscle, internal oblique muscle, and transversus abdominis muscle,[17] are divided parallel to the skin incision with electrocauterization. The extraperitoneal space is then entered for access to the aorta. The incision is extended into the tenth intercostal space if necessary, but rib resection is not performed. For about half of the patients, operative records did not indicate whether the incision extended into the intercostal space. Paramedian and flank incisions were made on the left side in all patients. Neither incision extended into the rectus abdominis muscle, and ligation of the inferior epigastric artery was not required.

### Measurement of muscle thickness and effect of incision

Measurements for each patient were made on the CT scan obtained before surgery and the final CT scan ob-

**Table I.** CPT% values for PM group on final CT scan

| | | *CPT% of rectus abdominis muscle* | | | *CPT% of lateral abdominal muscles* | | |
|---|---|---|---|---|---|---|---|
| *Patient* | *Months after surgery* | *L3* | *L5* | *S* | *L3* | *L5* | *S* |
| 1 | 2 | **64** | **50** | **54** | 100 | 102 | 100 |
| 2 | 11 | **56** | **50** | **50** | 95 | 104 | 100 |
| 3 | 14 | **44** | **40** | **30** | 116 | 100 | 100 |
| 4 | 24 | **36** | **36** | **31** | 90 | 97 | 92 |
| 5 | 25 | **80** | **27** | **25** | 100 | 100 | 93 |
| 6 | 25 | 83 | **42** | **30** | 98 | 100 | 102 |
| 7 | 31 | **78** | **27** | **18** | 116 | 97 | 100 |
| 8 | 42 | **73** | **25** | **21** | 105 | 94 | 96 |
| 9 | 50 | **28** | **44** | **33** | 93 | 96 | 100 |
| 10 | 59 | **33** | **15** | **21** | 100 | 96 | 85 |
| 11 | 64 | **25** | **40** | **33** | 101 | 100 | 100 |
| 12 | 65 | **70** | **30** | **37** | 96 | 106 | 100 |
| Mean | 34.33 | 55.83 | 35.50 | 31.92 | 100.83 | 99.33 | 97.33 |
| ±SD | 21.38 | 21.65 | 10.79 | 11.00 | 8.11 | 3.52 | 4.98 |

*CPT%,* Corrected percent thickness; *L3,* third lumbar vertebra; *L5,* fifth lumbar vertebra; *S,* center of sacrum.
Boldface, 20% or more decrease in CPT%.
Lightface, less than 20% decrease in CPT%.

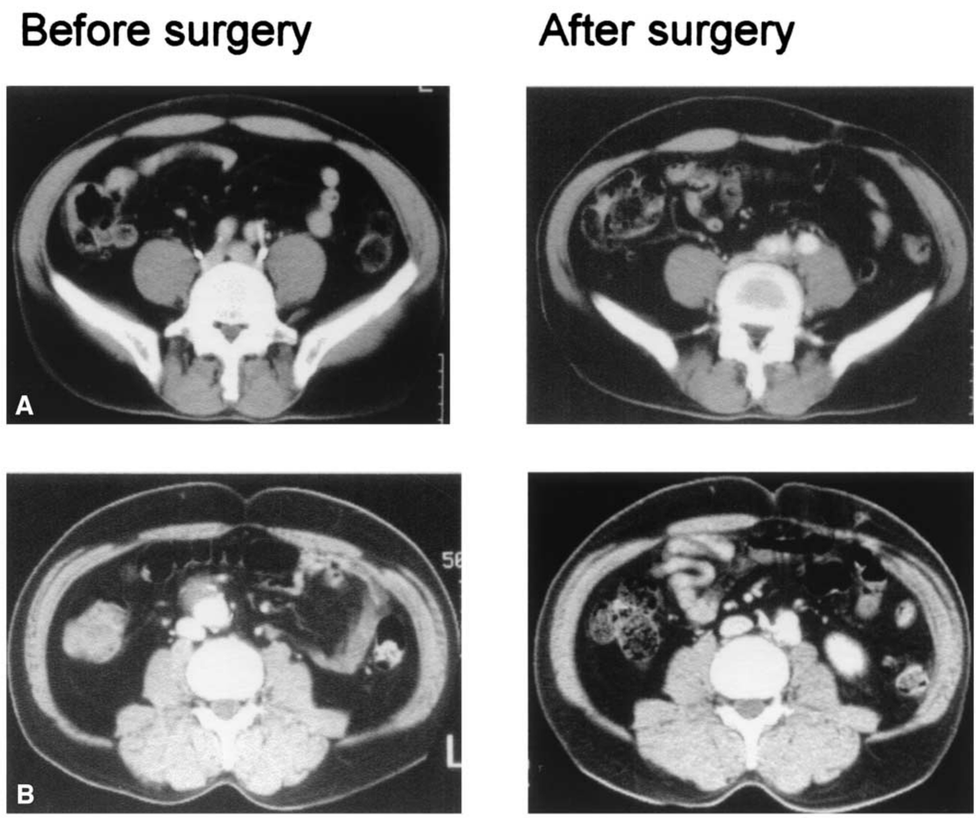


**Fig 2.** Examples of CT images in PM group. **A,** Patient 1. Note muscle atrophy in rectus abdominis muscle only 2 months after surgery, but thickness of lateral abdominal muscles did not change. **B,** Patient 4. Note remarkable atrophy only in rectus abdominis muscle 24 months after surgery.

tained 2 to 100 months after surgery. CT scans obtained at the level of the third lumbar vertebra (L3), fifth lumbar vertebra (L5), and center of the sacrum (S) were selected for measurement of muscle thickness. Comparable images were chosen by matching the bony shape of the adjacent spine throughout the series of CT examinations. The radiographs were scanned and magnified on an ES-8000 scanner (Seiko EPSON Corp, Tokyo, Japan) at 240 dpi with Adobe Photoshop (version 6.0; Adobe Systems, San Jose, Calif). Muscle thickness was measured with calipers against a calibrated scale shown on each CT image. The thickness of the rectus abdominis muscle and the lateral abdominal muscles was determined at their thickest points (Fig 1, *A*). We measured the thickest point of the atrophied segments of the lateral abdominal muscles in F group patients whose muscles were atrophied medially from the incision line; we also measured the thickness of the contralateral muscle at the corresponding point (Fig 1, *B*). Some F group patients also had atrophy of a broad area of the lateral abdominal muscles beyond the incision line. We measured the muscle at the thickest point in these patients (Fig 1, *C*). For consistency, image selection and measurements were made by a single observer (M.Y.).

We used these measurements to determine the effect of the incision on muscle atrophy. We considered the muscle thickness before surgery on the incision side to be 100% thickness (baseline value). Percent thickness, ie, thickness after surgery in relation to thickness before surgery, was calculated as $(T3/T1) \times 100$, where T1 and T3 are muscle thickness before and after surgery, respectively, on the incision side. Because muscle thickness may decrease naturally with age after surgery as well as from the effect of the incision, corrected percent thickness (CPT%), which represents the remaining muscle that has escaped incision-induced atrophy, was calculated according to the formula $CPT\% = (T3/T1) \times 100 \times (T2/T4)$, where T2 and T4 are muscle thickness before and after surgery, respectively, on the nonincision side. CPT% was calculated on the incision side in all patients.

Five radiologists, who had no knowledge of CPT% values, individually judged whether muscle atrophy could be recognized by comparison of the CT scan obtained after surgery with that obtained before surgery in all patients. All radiologists could recognize muscle atrophy in all muscles that had a calculated decrease 20% or more in CPT% value. No radiologist could recognize muscle atrophy in any muscles with a calculated decrease in CPT% value less than 10%. However, muscle atrophy could not be consistently recognized by the radiologists when the calculated decrease in CPT% value was greater than 10% and less than 20%.

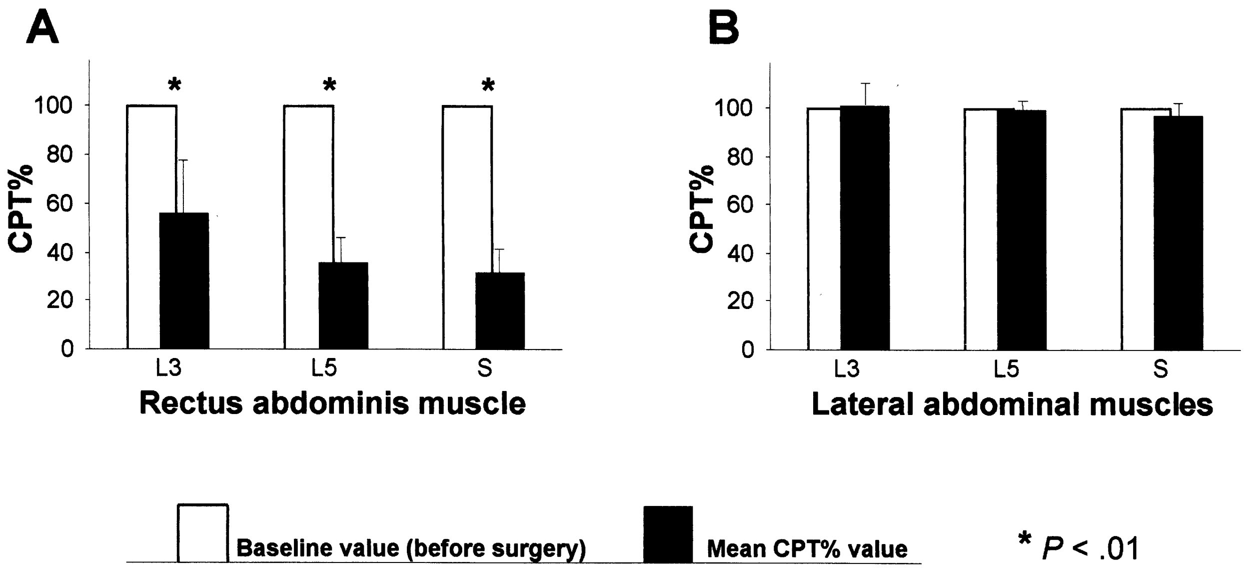


**Fig 3.** **A**, In PM group, mean corrected percent thickness (**CPT%**) values for rectus abdominis muscle were much smaller than baseline at CT scan levels of the third lumbar vertebra (**L3**), fifth lumbar vertebra (**L5**), and center of sacrum (**S**). **B**, Mean CPT% values for lateral abdominal muscles were not different from baseline at the three scanning levels.

Therefore we regarded decrease in CPT% of 20% or greater as a positive indication of muscle atrophy.

### Statistical analysis

CPT% values are reported in both groups as mean ± SD. All analyses were performed with statistical software (StatView 5.0; SAS Institute, Cary, NC). Differences between baseline value (100%) and CPT% values were assessed with the Wilcoxon signed rank test, as were differences in CPT% values between the two groups. Statistical significance was assumed at $P < .05$.

## RESULTS

### Degree of atrophy effected by incision

**PM group.** CPT% values for all 12 patients are shown in Table I. Values showing a decrease of 20% or more and values showing a decrease of less than 20% are indicated separately in Table I. Patient 1 (Fig 2, **A**) demonstrated atrophy in the rectus abdominis muscle only 2 months after surgery, but the thickness of the lateral abdominal muscles did not change. Patient 4 (Fig 2, **B**) exhibited remarkable atrophy only in the rectus abdominis muscle 24 months after surgery. All patients had a remarkable decrease in CPT% values in the rectus abdominis muscle, but none had atrophy in the lateral abdominal muscles. Duration from surgery to final CT scan was 2 to 65 months (mean ± SD, 34.33 ± 21.38 months; Table I). Comparison of baseline (100%) and mean CPT% value at the 3 scanning levels in all 12 patients is shown in Fig 3. Mean CPT% value of the rectus abdominis muscle was 55.83 ± 21.65% at L3, 35.50 ± 10.79% at L5, and 31.92 ± 11.00% at S, values statistically much smaller than baseline ($P < .01$). Mean CPT% value of the lateral abdominal muscles was 100.83 ± 8.11% at L3, 99.33 ± 3.52% at L5, and 97.33 ± 4.98% at S, values not statistically different from baseline.

**F group.** CPT% values are shown for all 27 patients in Table II. Values showing a decrease of 20% or more and values showing a decrease of less than 20% are indicated separately in Table II. In this group, patients demonstrated varying degrees of muscle atrophy. Patients 13 to 19 (Fig 4, *A*) had no atrophy in either the rectus abdominis muscle or the lateral abdominal muscles; patients 20 to 22 (Fig 4, *B*) showed atrophy only in the lateral abdominal muscles; and patients 23 to 31 (Fig 4, *C*) exhibited atrophy only in the rectus abdominis muscle. Atrophy in both the rectus abdominis muscle and lateral abdominal muscles was recognized in 8 patients (patients 32-39). Among these 8 patients, some had atrophy of only the medial part of the lateral abdominal muscles from the incision line (Fig 4, *D*), and the others had atrophy of a broad area of the lateral abdominal muscles (Fig 4, *E*). Duration from surgery to final CT scan was 3 to 96 months (mean, 27.85 ± 20.74 months; Table II). Comparison of baseline (100%) and mean CPT% values at the three scanning levels for all 27 cases are shown in Fig 5. Mean CPT% value of the rectus abdominis muscle was 100.67 ± 5.02% at L3, not statistically different from baseline. Mean CPT% value of the rectus abdominis muscle was 82.19 ± 23.15% at L5 and 64.41 ± 31.34% at S, values statistically smaller than baseline ($P < .01$). Mean CPT% value of the lateral abdominal muscles was 87.59 ± 22.30% at L3 and 84.59 ± 26.90% at L5, values statistically smaller than baseline ($P < .05$). Mean CPT% value of the lateral abdominal muscles was 98.07 ± 16.61% at S, not statistically different from baseline.

**Table II.** CPT% values for F group on final CT scan

| | | *CPT% of rectus abdominis muscle* | | | *CPT% of lateral abdominal muscles* | | |
|---|---|---|---|---|---|---|---|
| *Patient* | *Months after surgery* | *L3* | *L5* | *S* | *L3* | *L5* | *S* |
| 13 | 3 | 100 | 99 | 117 | 100 | 108 | 107 |
| 14 | 8 | 95 | 99 | 86 | 100 | 100 | 100 |
| 15 | 12 | 101 | 109 | 92 | 111 | 100 | 109 |
| 16 | 15 | 100 | 100 | 100 | 93 | 100 | 100 |
| 17 | 16 | 99 | 105 | 90 | 106 | 106 | 100 |
| 18 | 42 | 100 | 97 | 97 | 95 | 101 | 100 |
| 19 | 46 | 106 | 106 | 100 | 105 | 92 | 100 |
| 20 | 11 | 100 | 100 | 82 | 105 | **78** | 102 |
| 21 | 20 | 97 | 100 | 102 | 100 | **66** | 105 |
| 22 | 36 | 110 | 108 | 110 | 94 | **20** | 108 |
| 23 | 8 | 100 | **78** | **40** | 100 | 100 | 98 |
| 24 | 12 | 97 | **75** | **41** | 91 | 106 | 100 |
| 25 | 18 | 100 | 100 | **46** | 95 | 100 | 92 |
| 26 | 18 | 100 | **62** | **40** | 100 | 105 | 100 |
| 27 | 20 | 105 | **58** | **29** | 98 | 98 | 100 |
| 28 | 33 | 100 | **63** | 92 | 100 | 105 | 100 |
| 29 | 34 | 94 | **80** | **64** | 90 | 98 | 103 |
| 30 | 45 | 108 | 98 | **75** | 104 | 108 | 104 |
| 31 | 57 | 94 | 104 | **74** | 100 | 94 | 108 |
| 32 | 10 | 100 | **44** | **35** | **59** | 93 | 100 |
| 33 | 13 | 97 | **61** | **28** | **44** | 90 | 102 |
| 34 | 17 | 98 | **53** | **44** | **36** | 100 | 100 |
| 35 | 24 | 100 | **67** | **38** | 100 | **35** | 100 |
| 36 | 33 | 114 | **40** | **18** | **73** | **44** | 93 |
| 37 | 51 | 100 | 100 | **27** | **32** | **30** | 92 |
| 38 | 54 | 109 | **36** | **17** | **74** | **47** | **18** |
| 39 | 96 | 94 | **77** | **55** | **60** | **60** | 107 |
| Mean | 27.85 | 100.67 | 82.19 | 64.41 | 87.59 | 84.59 | 98.07 |
| ±SD | 20.74 | 5.02 | 23.15 | 31.34 | 22.30 | 26.90 | 16.61 |

*CPT%,* corrected percent thickness; *L3,* third lumbar vertebra; *L5,* fifth lumbar vertebra; *S,* center of sacrum.
Boldface, 20% or more decrease in CPT%.
Lightface, less than 20% decrease in CPT%.

### Difference in degree of atrophy between PM and F groups

Mean duration from surgery to final CT scan, from which CPT% values were calculated, was 34.33 ± 21.38 months in PM group and 27.85 ± 20.74 months in F group (Tables I, II), values not statistically different between groups. CPT% values, shown in Tables I and II, are compared in Fig 6. The degree of rectus abdominis muscle atrophy was greater in PM group than in F group at all three scanning levels ($P < .01$), but there were no significant differences in lateral abdominal muscle atrophy between groups.

### Relation between varieties of atrophy and incision in F group

Because about half of the operative records included no details on the incision into the intercostal space, the relation between degree of muscle atrophy and the performed incision in F group could not be determined.

## DISCUSSION

CT scan assessment revealed that all patients in PM group had severe rectus abdominis muscle atrophy and no atrophy in the lateral abdominal muscles. Rectus abdominis muscle atrophy was also seen in F group, but the degree of atrophy was much less than that in PM group; however, some patients in F group exhibited atrophy of the lateral abdominal muscles.

Few reports are available that discuss assessment of abdominal muscles on CT scans after surgery,[14] but many studies report abdominal bulge. The reported incidence of abdominal bulge induced by the extraperitoneal approach is 11% to 23%.[7,9] Abdominal bulge is defined as any obvious asymmetry between the right and left sides when the patient is standing[9]; it is not an objective assessment. In this study we did not assess abdominal bulge and clinical status during follow-up, because some study patients were no longer followed up at our hospital. However, in PM group, abdominal bulge was recognized in some patients, and 1 patient complained of decreased abdominal muscle

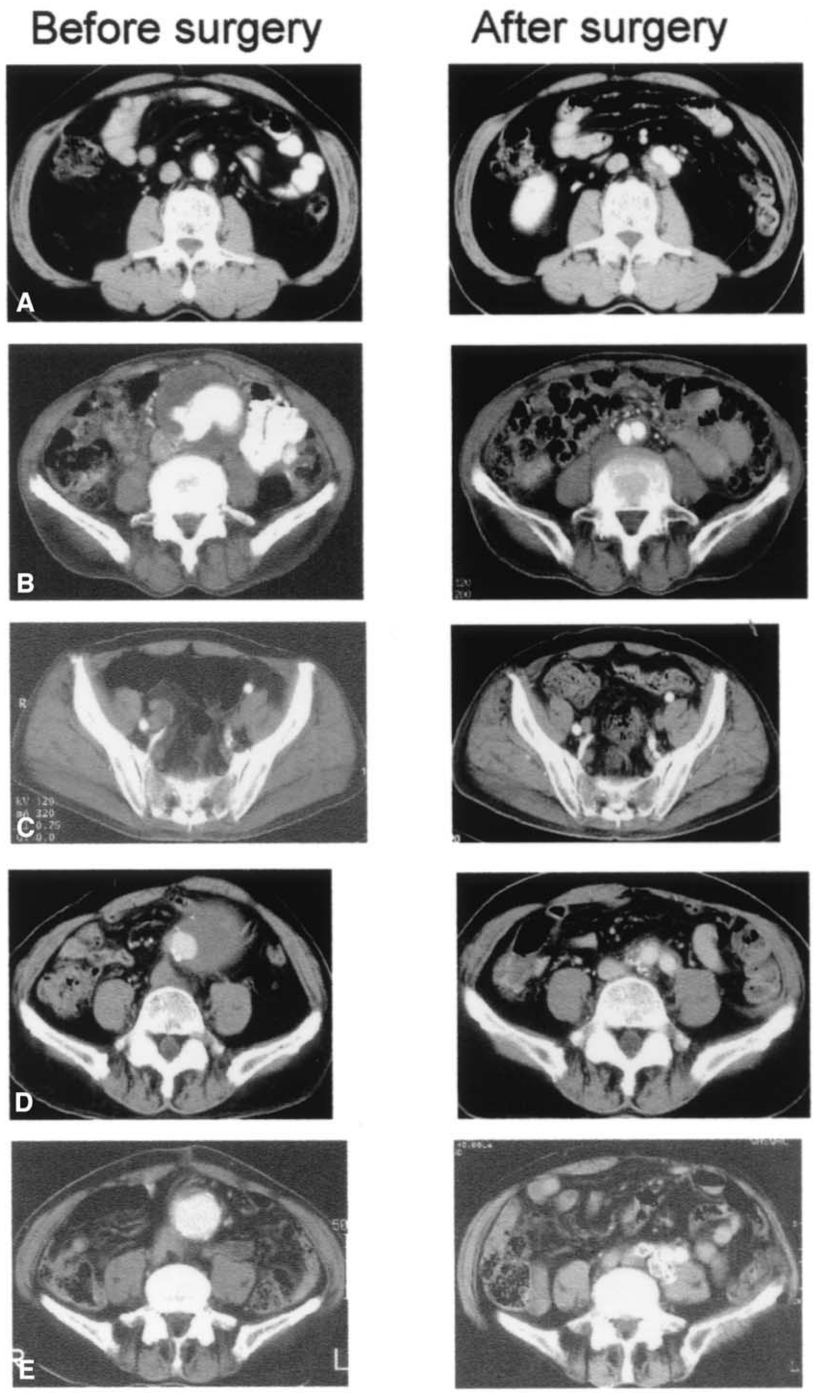


**Fig 4.** Examples of CT images in F group. **A,** Patient 18 had no muscle atrophy in rectus abdominis muscle or lateral abdominal muscles. **B,** Patient 22 exhibited muscle atrophy only in lateral abdominal muscles. **C,** Patient 30 had muscle atrophy only in rectus abdominis muscle. **D,** Patient 36 demonstrated muscle atrophy in rectus abdominis muscle and in only medial part of lateral abdominal muscles from incision line. **E,** Patient 38 exhibited muscle atrophy in rectus abdominis muscle and broad area of lateral abdominal muscles.

strength when he sang. Because of these outcomes, we changed from the paramedian incision to the flank incision in 1991. Even so, a small number of F group patients who received the flank incision had both abdominal bulge and muscle atrophy. During follow-up no patients had abdominal hernia, which is easily diagnosed on CT scans as com-

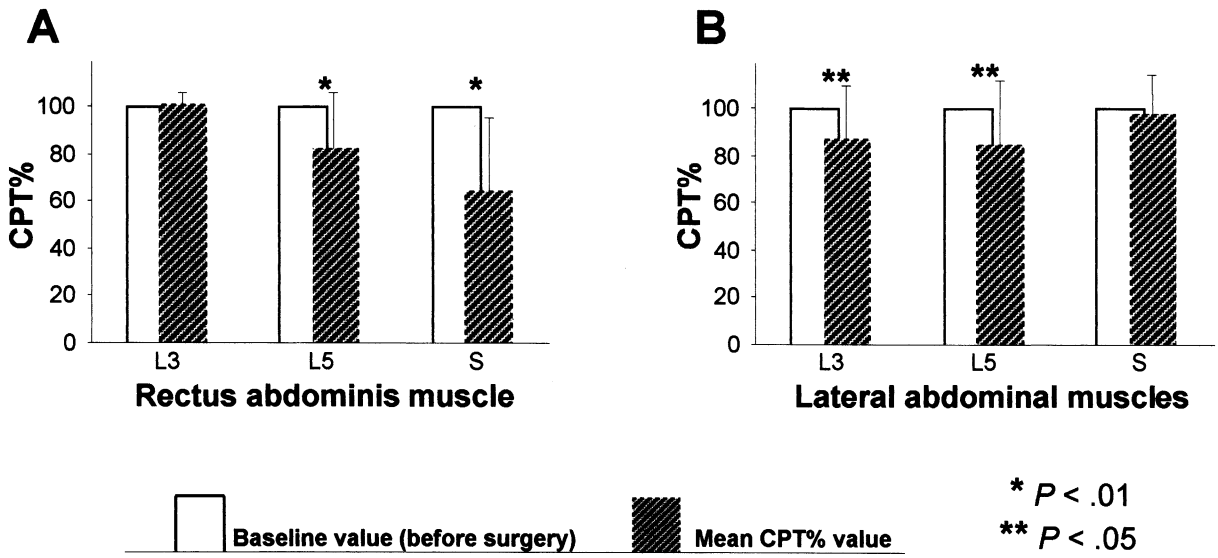


**Fig 5.** **A**, In F group, mean corrected percent thickness (**CPT%**) values for rectus abdominis muscle were smaller than baseline at CT scan levels of fifth lumber vertebra (**L5**) and center of sacrum (S). B, Mean CPT% values of lateral abdominal muscles were smaller than baseline at CT scan levels of third lumbar vertebra (L3) and fifth lumbar vertebra (**L5**).

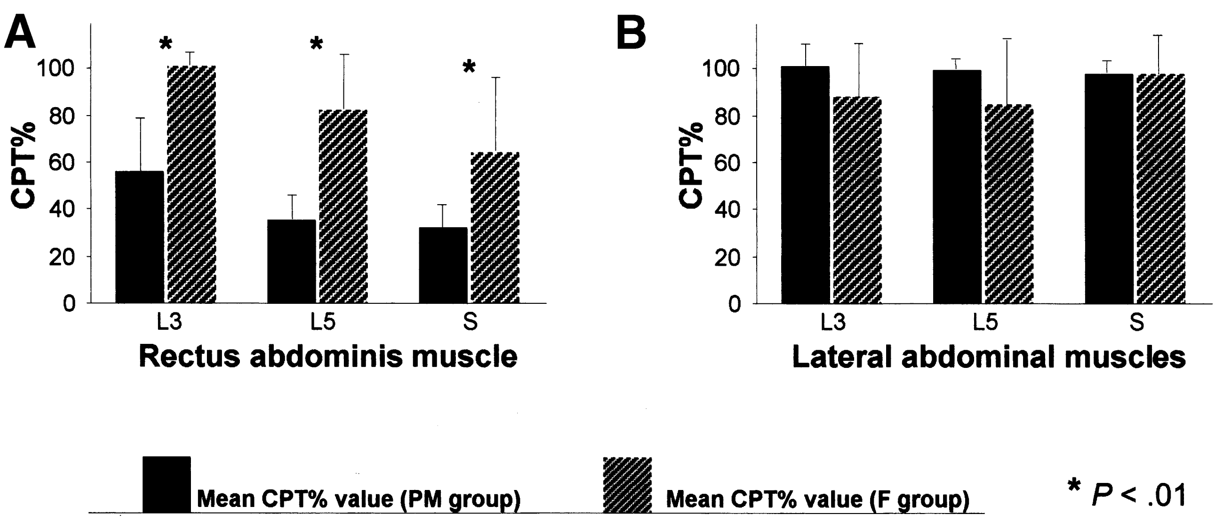


**Fig 6.** **A**, Mean corrected percent thickness (**CPT%**) values for rectus abdominis muscle were much smaller in PM group than in F group at CT scan levels of third lumbar vertebra (**L3**), fifth lumbar vertebra (**L5**), and center of sacrum (**S**). **B**, There were no significant differences in mean CPT% values for lateral abdominal muscles between groups at the three scanning levels.

plete fascial and muscular disruption, and no patients in either PM or F group required further surgery to repair the abdominal muscle wall.

One cause of localized muscle atrophy is direct muscle injury due to incision and suture; broader areas of muscle atrophy are induced by denervation and reduced blood supply.[8,10-13] We report specifically on atrophy of the rectus abdominis muscle and the lateral abdominal muscles, ie, external and internal oblique muscles and transversus abdominis muscle.[17] The rectus abdominis muscle derives its blood supply mainly from the superior and inferior epigastric arteries, which are connected. The paramedian incision does not reduce blood supply to this muscle.[10-12] The lateral abdominal muscles are supplied by the intercostal arteries, deep circumflex iliac artery, subcostal artery, lumbar artery, and superior and inferior epigastric arteries. Because these arteries anastomose with each other,[10,18,19] the flank incision also does not reduce blood supply to the lateral abdominal muscles. Therefore we believe that the muscle atrophy in our patients was caused mainly by denervation. The fifth to eleventh intercostal nerves and the subcostal nerve pass between the internal oblique and transversus abdominis muscles, branch multiply to the lateral abdominal muscles, and enter the rectus abdominis muscle. The paramedian incision, which cuts multiple intercostal nerves, induces complete denervation of the rectus abdominis muscle. The fifth to eleventh intercostal nerves and the subcostal, iliohypogastric, and ilioinguinal nerves innervate the external and internal oblique muscles. The seventh to eleventh intercostal nerves and the subcostal, iliohypogastric, and ilioinguinal nerves innervate the transversus abdominis muscle.[10-13,17-20] These nerves are connected with each other.[17,19,20] Muscle atrophy may not develop if the flank incision is performed within the same dermatome, especially along with intercostal nerve. Muscle atrophy may not be noticeable because of the presence of these connections, even if one or two of the main branches of these nerves are cut. These nerve distributions are anatomically different between individuals[8,18,19,21] and also may be different between races.

Our study was retrospective, with a relatively small number of patients. Duration of follow-up and timing of CT performed after surgery were variable among study patients. Also, surgery was performed at different times in each group; PM group operations were performed before 1991, and F group operations were performed after 1991. Even considering these factors, we believe there were remarkable differences in degree of muscle atrophy between PM group and F group. In the operative records for F group patients, information on incision type was not sufficient to prove the relation between incision type and muscle atrophy, but many patients had almost no atrophy in either the rectus abdominis or lateral abdominal muscles. Several excellent reports discuss the innervation and blood supply of the anterolateral abdominal muscles.[8,10-13,17-21] Understanding of this anatomy and further investigation into the relation between incision site and anatomy may contribute to prevention of muscle atrophy after flank incision.

## CONCLUSIONS

Both the paramedian and flank incisions for extraperitoneal approach to the infrarenal abdominal aorta induced anterolateral abdominal muscle atrophy. The paramedian incision induced severe rectus abdominis muscle atrophy, with no atrophy in the lateral abdominal muscles, in all patients. The flank incision also induced rectus abdominis muscle atrophy, but the degree of atrophy was much less than that induced by the paramedian incision. The flank incision induced various degrees of atrophy in both the rectus abdominis muscle and the lateral abdominal muscles, but some patients in this group did not exhibit any muscle atrophy. These data indicate that further anatomic investigation into the relation between the flank incision and abdominal wall innervation may contribute to prevention of muscle atrophy after flank incision.

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