

The Dexamethasone-Suppressed Corticotropin-Releasing Hormone Stimulation Test Differentiates Mild Cushing's Disease from Normal Physiology

JACK A. YANOVSKI*†, GORDON B. CUTLER, JR.†, GEORGE P. CHROUSOS, AND
LYNNETTE K. NIEMAN

Office of the Director (J.A.Y.), Warren Grant Magnuson Clinical Center and The Developmental Endocrinology Branch (J.A.Y., G.B.C, G.P.C., L.K.N.), National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Maryland 20892-1862

ABSTRACT

The dexamethasone-suppressed CRH test (Dex-CRH test) differentiates patients with Cushing's syndrome (CS) from those with pseudo-Cushing states, who have decreased ACTH responses to CRH because of negative feedback exerted by chronic hypercortisolism. Normal subjects, however, have not been studied with the Dex-CRH test, raising concern that this test might not separate patients with CS from patients with normal adrenal function. To determine whether the criterion that separates CS from pseudo-Cushing states also would differentiate patients with Cushing's disease (CD) from individuals with eucortisolism, we studied 20 healthy volunteers during low-dose (2 mg/day) dexamethasone suppression, and then during the Dex-CRH test (CRH stimulation test performed 2 h after completion of low-dose dexamethasone suppression), and contrasted their results with those of 20 patients with surgically proven mild CD [urine free cortisol (UFC) <1000 nmol/day).

Basal UFC was significantly greater in patients with CD ($P <$

0.001) but within the normal range (55–250 nmol/day) in 4 patients. During low-dose dexamethasone suppression, a UFC less than 100 nmol/day (36 μ g/day) was found in all but 1 volunteer subject, and a urine 17-hydroxycorticosteroid excretion less than 14.6 μ mol/day (5.3 mg/day) was found in all but 2 subjects. During the Dex-CRH test, plasma cortisol less than 38 nmol/L was found in all 20 normal volunteers until 30 min after CRH administration. By contrast, the 15-min CRH-stimulated plasma cortisol exceeded 38 nmol/L in all patients with CD ($P < 0.001$). Plasma dexamethasone measured just before CRH administration was similar in normal volunteers ($13.0 \pm 6.1 \mu$ mol/L) and patients with CD ($16.4 \pm 6.4 \mu$ mol/L). We conclude that cortisol measurements obtained during the Dex-CRH test are suppressed in normal volunteers below those found in mild CD. These results suggest that the Dex-CRH test may be useful in the evaluation of CS in patients without significant hypercortisoluria. However, its value in patients with episodic hormonogenesis has not been tested. (*J Clin Endocrinol Metab* 83: 348–352, 1998)

SEVERAL tests are currently in clinical use to differentiate Cushing's syndrome (CS) from conditions causing pseudo-Cushing states (PCS), such as depression, stress, renal failure, alcoholism, or obesity. The low-dose dexamethasone suppression test (1–3) measures 17-hydroxycorticosteroid excretion during administration of dexamethasone, 0.5 mg every 6 h for 2 days. When 17-hydroxycorticosteroid excretion exceeds 11.0 μ mol/day (4 mg/day) (4), the test is considered positive for CS. However, this test may misclassify as many as 15% of patients with CS and up to 15% of patients with PCS (5). The CRH stimulation test, valuable in differentiating the syndrome of ectopic ACTH from Cushing's disease (CD) (6, 17), is also of limited use in the differential diagnosis between PCS and CD because there is considerable overlap with the responses of patients with CD (5, 7–9). Other tests to distinguish CD from PCS have been described but not fully tested (4, 10).

The lack of a test with both high sensitivity and high specificity for CS led to the development of the dexametha-

son-suppressed CRH (Dex-CRH) test. In a pilot study, 39 patients with CS and 19 patients believed to have PCS were given dexamethasone (0.5 mg/dose every 6 h for 8 doses) followed by administration of 1 μ g/kg ovine CRH 2 h after the last dose of dexamethasone. In this study, a plasma cortisol value (measured 15 min after CRH administration) that was greater than 38 nmol/L had 100% diagnostic accuracy for CS, and the Dex-CRH test had superior sensitivity and diagnostic accuracy when compared either with the low-dose dexamethasone suppression test or with the CRH test performed alone (5).

Patients with PCS have decreased ability to secrete ACTH in response to CRH because of the glucocorticoid negative feedback exerted by chronic hypercortisolism (11). However, many patients referred for endocrinologic evaluation, to rule out CS, either have no evidence for hypercortisoluria, or minimal elevation of urine free cortisol (UFC) or 17-hydroxycorticosteroids (17OHCS). Because such individuals have not been exposed to chronic hypercortisolism, they might have a greater ACTH and cortisol response to the Dex-CRH test than those with a sustained PCS. To determine whether the criterion that separates CS from PCSs also will distinguish CS from individuals without hypercortisolism, we compared the results of the Dex-CRH test in 20 normal volunteers and in 20 patients with CD.

Received March 17, 1997. Revision received May 15, 1997. Rerevision received July 22, 1997. Accepted October 24, 1997.

* To whom correspondence and requests for reprints should be addressed, at Building 10, Room 10N262, National Institutes of Health, Bethesda, Maryland 20892-1862. E-mail: yanovskj@cc1.nichd.nih.gov.

† Commissioned officers in the U.S. Public Health Service.

Subjects and Methods

Subjects

Twenty volunteers (22–58 yr old; 10 males and 10 females) were recruited through posted notices in the Bethesda, MD area (Table 1). Twenty patients with surgically-proven CD were referred to NIH for evaluation of mild hypercortisolism (UFC < 1000 nmol/day; normal range: 50–250 nmol/day) between May 1992 and February 1994, and have not been the subjects of any prior report. These 20 patients underwent biochemical tests to determine the cause of their CS (12, 13, 14, 15). Based on results of testing, they underwent transsphenoidal pituitary exploration, which revealed an adenoma with ACTH staining in each case. All normal volunteers were medication-free for at least 2 weeks before the start of the study, and all were free of significant medical disease. None of the normal volunteers had evidence of any psychiatric disorder known to affect the hypothalamic-pituitary adrenal axis, and all had refrained from the use of any steroid preparation for a minimum of 3 months before study. The study was approved by the NIH Intramural Clinical Research Subpanel, and each subject gave written consent for participation.

Study protocol

In all subjects, the 24-h excretion of UFC, 17OHCS, and creatinine was measured for 1 day while subjects took no glucocorticoids, and subsequently, during administration of 0.5 mg dexamethasone orally every 6 h for 8 doses, starting at 1200 h.

A Dex-CRH test was performed in all subjects, starting 2 h after the patient had completed dexamethasone treatment. Ovine CRH (Bachem, Torrance, CA) was administered as an iv bolus injection at a dose of 1 μ g/kg between 0800 and 0810 h. Plasma samples were assayed for cortisol and ACTH at –15, –10, –5, and –1 min before CRH stimulation and then at 5, 15, 30, 45, and 60 min after CRH; and for dexamethasone, at –1 min. Normal volunteers underwent CRH testing in the endocrine outpatient clinic. Patients with CD were admitted to the inpatient endocrinology ward of the Warren Grant Magnuson NIH Clinical Center for testing.

Hormone assays

UFC, 17OHCS, and creatinine were measured as previously described (12). The intraassay and interassay variabilities were 8–12% and 8–15% for UFC, 6–12% and 7–20% for 17OHCS, and 1% and 2% for creatinine. Daily creatinine measurements varied by no more than 10%. Plasma ACTH and cortisol were measured, as previously described (6), by Corning Hazleton Laboratories (Vienna, VA). The sensitivity for the ACTH assay ranged from 0.9–2.2 pmol/L and for cortisol, from 5.5–22 nmol/L. The intraassay and interassay variabilities were 7–12% and 12–25% for ACTH, and 6 and 15% for cortisol. Each cortisol sample also was measured in a second, serum cortisol assay, performed by the Clinical Pathology Laboratory of the NIH Clinical Center, using the Abbott TDX kit (Abbot Park, IL). Results were equivalent, except that Abbott kit cortisol determinations had a higher limit of detection (27.6 nmol/L) than those measured at Corning Hazleton Laboratories (5.5–22 nmol/L). In this report, results from the Corning Hazleton Laboratories plasma cortisol assay are given. Plasma samples were assayed for dexamethasone by Endocrine Sciences (Calabasas Hills, CA). The intraassay and interassay variabilities for the plasma dexamethasone assay were 3.4% and 8.4%, respectively.

TABLE 1. Study patients

	Healthy volunteers (n = 20)	Cushing disease (n = 20)
Age (yr)	32.6 \pm 9.8	37.5 \pm 10.9
Body mass index (kg/m ²)	24.3 \pm 3.6	35.3 \pm 14.5 ^a
Gender	10 Male 10 Female	16 Female
Race	19 Caucasian, 1 Hispanic	18 Caucasian, 1 Hispanic, 1 Pacific Islander
Basal 24-h urine-free cortisol excretion, nmol/day (normal 50–250 nmol/day)	103 \pm 73	493 \pm 252 ^a
Basal 17-hydroxycorticosteroid excretion, μ mol/day (normal 5.5–22.0 nmol/day)	15.8 \pm 7.3	46.9 \pm 17.7 ^a

Mean \pm SD.

^a $P < 0.001$ Cushing disease vs. healthy volunteers.

Data analysis

Data were analyzed on a Macintosh Power PC using SuperAnova and StatView 4.5 (Abacus Concepts, Inc., Berkeley, CA), and RuleMaker (Digital, Hanover, MA). After logarithmic data transformation, ANOVA (with repeated measures) was performed for plasma cortisol and plasma ACTH measurements, employing a conservative (Greenhouse-Geisser) F test. The relation between the dexamethasone level and plasma cortisol was determined by simple regression. After dexamethasone administration, UFC and 17OHCS were not normally distributed, and they were analyzed using the Mann-Whitney nonparametric test using the Bonferroni correction for multiple comparisons. Tabular data are presented as mean \pm SD.

Estimates of sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were determined for each test statistic (16). The sensitivity and diagnostic accuracy of each of the test criteria were compared at 100% specificity by χ -square statistics (17). We compared the criteria for the diagnosis of CD of the various tests, using cut-points with 100% specificity for the diagnosis of CS from PCS found in our previous retrospective study (5).

Results

Low-dose dexamethasone suppression

Urine 17-hydroxycorticosteroid and free cortisol were measured before and during dexamethasone administration in all subjects. Both urine 17-hydroxycorticosteroid and free cortisol excretion were significantly greater in patients with CD (Table 1, $P < 0.001$). UFC was within the normal range (55–250 nmol/day) in 4 of the 20 patients with CD (none with episodic hypersecretion of cortisol), and greater than the normal range in 1 normal volunteer (290 nmol/L).

Both UFC and 17OHCS decreased significantly after dexamethasone administration in both groups (Tables 2 and 3, $P < 0.001$). During the second day of dexamethasone suppression, one normal volunteer had a UFC greater than 100 nmol/day (36 μ g/day), and two normal volunteers had urine 17-hydroxycorticosteroid excretion more than 14.6 μ mol/day (5.3 mg/day). These values represented cut-points with 100% specificity for the diagnosis of CS in our previous retrospective study (5). Use of lower values of urinary 17OHCS or UFC as the cut-points for the diagnosis of CD yielded similar results: a 17-hydroxycorticosteroid more than 6.9 μ mol/day (2.5 mg/day) for the diagnosis of CD had 90% sensitivity and 65% specificity; a UFC criterion more than 56 nmol/day (20 μ g/day) had 75% sensitivity and 93% specificity for the diagnosis of CD.

CRH test with dexamethasone pretreatment (Dex-CRH test)

All subjects completed the Dex-CRH test (Fig. 1, Tables 2 and 3). ANOVA showed significant group-by-time interac-

TABLE 2. Results following dexamethasone suppression

	Healthy volunteers (n = 20)	Cushing disease (n = 20)
Plasma dexamethasone, $\mu\text{mol/L}$	13.0 ± 6.1	16.4 ± 6.4
Dexamethasone-suppressed urine-free cortisol excretion, nmol/day	16.0 ± 20.1^a	$168.3 \pm 144^{a,b}$
Dexamethasone-suppressed 17-hydroxycorticosteroid excretion, $\mu\text{mol/day}$	6.9 ± 4.5^a	$16.9 \pm 9.1^{a,b}$
Dexamethasone-suppressed basal plasma cortisol, nmol/L	27.1 ± 3.6	152 ± 185^b
Dexamethasone-suppressed plasma cortisol 15 min after CRH, nmol/L	27.4 ± 4.0	256 ± 195^b

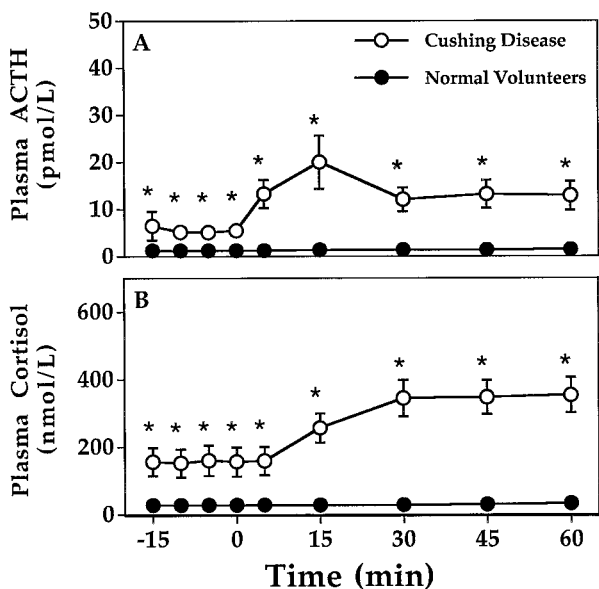
Mean \pm SD.^a $P < 0.001$ vs. measurement before administration of dexamethasone.^b $P < 0.001$ Cushing disease vs. healthy volunteers.

FIG. 1. Results of CRH stimulation testing with low-dose dexamethasone pretreatment. Plasma ACTH in patients with CD (A) and in normal volunteers (C). Plasma cortisol in patients with CD (B) and in normal volunteers (D). Means and SE of measurement are shown when SEM is greater than size of data point. ●, CD; ○, healthy volunteers; *, $P < 0.001$, CD vs. healthy volunteers. Note differing y-axis scaling for CD and for normal volunteers, which is required to show each data point.

tions ($P < 0.001$). Plasma ACTH increased significantly in both groups (basal ACTH: 6.47 ± 3.0 , peak ACTH: 25.2 ± 27.1 pmol/L, $P < 0.001$ for CD; basal ACTH: 1.19 ± 0.05 , peak ACTH: 1.56 ± 0.14 pmol/L, $P < 0.04$ for normal volunteers). Plasma cortisol rose significantly in patients with CD (basal cortisol: 156.14 ± 41.64 , peak cortisol: 471.58 ± 67.02 nmol/L, $P < 0.001$) but did not change significantly in normal volunteers (basal cortisol: 27.29 ± 0.83 , peak cortisol: 31.92 ± 2.57 nmol/L, $P = 0.07$). Both plasma ACTH and cortisol were significantly greater in patients with CD at all time points ($P < 0.001$).

As was previously observed in individuals with PCS, a Dex-CRH test plasma cortisol concentration less than 38 nmol/L was found in all 20 normal volunteers, both basally and at all times between 0 and 30 min after administration of CRH (Fig. 1). The plasma cortisol of 2 normal volunteers exceeded 38 nmol/L at 45 and 60 min after CRH. A plasma cortisol less than 38 nmol/L was found before administration of CRH in 4 patients with CD (Fig. 2A); but in all cases, a cortisol concentration in excess of 38 nmol/L was found 15

min after CRH stimulation (Fig. 2B). The criterion for dexamethasone-suppressed plasma ACTH that was best for distinguishing CD was a plasma ACTH more than 3.5 pmol/L at 30 min (Fig. 2C), which had 100% specificity and 90% sensitivity for the diagnosis of CD. Results using peak ACTH or peak cortisol response did not have 100% diagnostic accuracy.

The mean plasma dexamethasone level (Table 2) measured just before CRH administration did not differ for normal volunteers (13.0 ± 6.1 $\mu\text{mol/L}$; 469.5 ± 220.4 ng/dL) and patients with CD (16.4 ± 6.4 $\mu\text{mol/L}$; 614.8 ± 233.1 ng/dL). The two normal volunteers, whose plasma cortisol exceeded 38 nmol/L at 45 and 60 min after CRH, had the two lowest plasma dexamethasone values (6.90 and 4.03 $\mu\text{mol/L}$). In patients with CD, dexamethasone levels and plasma ACTH or cortisol measurements were not correlated, either at basal or CRH-stimulated time points ($P = 0.41$, data not shown).

Comparison of tests

When compared, at criteria yielding 100% specificity for the diagnosis of CD, the Dex-CRH test 15-min cortisol concentration had significantly greater sensitivity and diagnostic accuracy than dexamethasone-suppressed urine 17-hydroxycorticosteroid or free cortisol measurements (Table 3). Although basal plasma cortisol after dexamethasone administration did not correctly identify four patients with CD, this 80% sensitivity, when compared with the 100% sensitivity of the CRH-stimulated plasma cortisol level, was not statistically significant ($P = 0.3$). Similar results were found using peak CRH-stimulated ACTH, ACTH 30 min after CRH stimulation, or peak CRH-stimulated cortisol values (Table 3).

Discussion

In this study, the Dex-CRH test (a new test for the differential diagnosis of hypercortisolism) distinguished all patients with mild CD from healthy volunteers, using criteria previously established to discriminate pseudo-Cushing states from CD. The Dex-CRH-stimulated cortisol value, obtained 15 min after administration of CRH, had better diagnostic accuracy for the diagnosis of CD than either basal 24-h urine 17-hydroxycorticosteroid measurements or dexamethasone-suppressed urine measurements. Although the 15-min Dex-CRH test did not have significantly greater diagnostic accuracy than basal UFC ($P = 0.06$), basal dexamethasone-suppressed plasma cortisol ($P = 0.3$), peak dexamethasone-suppressed plasma cortisol ($P = 0.6$), or Dex-CRH plasma ACTH ($P = 0.6$), the Dex-CRH test 15-min cortisol criterion was the only evaluated criterion with both 100% specificity

TABLE 3. Comparison of tests

Test variable	Criterion	Specificity	Sensitivity	+ Pred. value	- Pred. value	Diagnostic accuracy
DEX-CRH test cortisol 15' after CRH	>38.6 nmol/L	1.00	1.00	1.00	1.00	1.00
Dex-CRH test basal cortisol	>38.6 nmol/L	1.00	0.80	1.00	0.83	0.90
Dex-CRH test peak cortisol	>44.2 nmol/L	1.00	0.80	1.00	0.83	0.90
Dex-CRH test ACTH 30' after CRH	>3.5 pmol/L	1.00	0.90	1.00	0.91	0.95
Dex-CRH test peak ACTH	>3.5 pmol/L	1.00	0.90	1.00	0.91	0.95
Basal 17-OHCS	>34.5 μ mol/day	1.00	0.55 ^a	1.00	0.69 ^a	0.78 ^a
Basal UFC	>290 nmol/day	1.00	0.75	1.00	0.80	0.87
Low-dose dex 17-OHCS	>17.9 μ mol/day	1.00	0.60 ^a	1.00	0.71 ^a	0.80 ^a
Low-dose dex UFC	>128.8 nmol/day	1.00	0.50 ^a	1.00	0.67 ^a	0.75 ^a

Comparison of criteria with 100% specificity for the diagnosis of Cushing disease. UFC, Urine free cortisol excretion; 17-OHCS, urine 17-hydroxycorticosteroid excretion.

^a $P < 0.05$, vs. Dex-CRH test 15-min cortisol.

and sensitivity. Though the overnight 1-mg dexamethasone suppression test would likely eliminate at least 90% of normocortisolic individuals from consideration of the diagnosis of CS, the overnight 1-mg dexamethasone suppression test is of lesser value in differentiating individuals with PCS and CS (4). Because we wished to evaluate a test that could differentiate patients with CS from all individuals without the disorder, we did not perform the 1-mg test in the subjects of the present study.

Most patients with CD show some suppression of ACTH and cortisol by dexamethasone (6, 8, 12, 13, 18) and some stimulation of ACTH and cortisol by CRH (6, 14). However, cortisol secretion decreases greatly in some patients with CD during low-dose dexamethasone, possibly because of slow dexamethasone clearance (19, 20). Such patients may be misclassified as having PCS if evaluated only by suppression of cortisol production after low-dose dexamethasone administration. In the present study, four subjects with CD had dexamethasone-suppressed basal plasma cortisol values less than 38 nmol/L. By the addition of CRH, to stimulate greater ACTH and cortisol secretion in patients with CD who are CRH-sensitive, those patients with unusual sensitivity to dexamethasone suppression achieve greater ACTH and cortisol levels, above those of patients with PCS (5) or normal volunteers. In this manner, the Dex-CRH test correctly identifies more patients with CD than does low-dose dexamethasone suppression, and therefore allows the criterion for the diagnosis of CS to be 100% specific, with a much higher sensitivity than is possible with dexamethasone suppression alone.

Four of the patients with CD in this study had basal UFC excretion that was within the normal range. All four of these patients had Dex-CRH-stimulated cortisol levels greater than the 38 nmol/L cut-point identified in our previous study (5) and were correctly identified by the Dex-CRH test. In contrast, healthy volunteers showed suppression of plasma ACTH and cortisol similar to that observed previously for patients with PCS (5). These results lead us to believe that the Dex-CRH test may be of value for determining who has true CS among patients with normal, or only mildly elevated, UFC measurements. However, the value of the Dex-CRH test in classifying those who have CS with periodic hormonogenesis (21–25), but who are not hypercortisolemic at the time of testing, remains unknown.

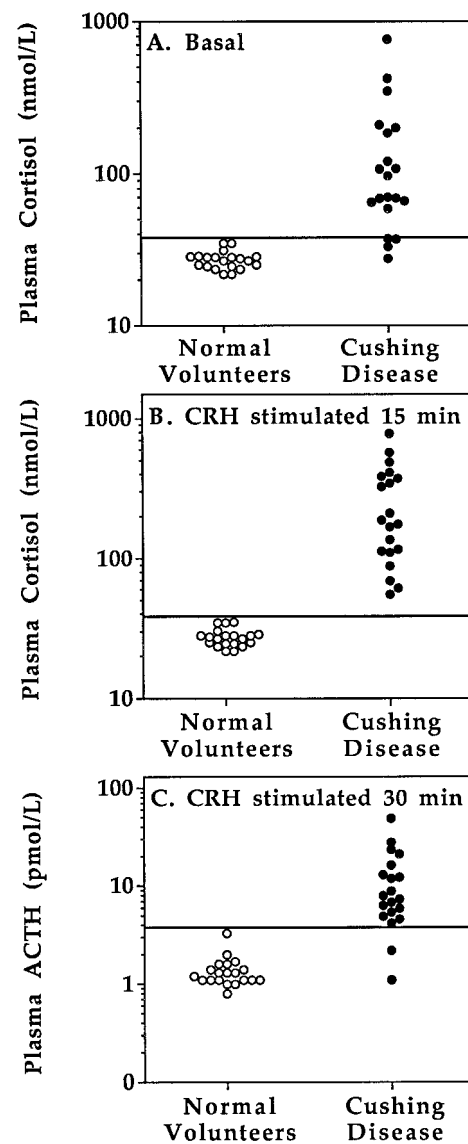


FIG. 2. Individual data showing the criteria with the best diagnostic accuracy. A, Basal plasma cortisol after dexamethasone-suppression; B, Dex-CRH plasma cortisol obtained 15 min after CRH stimulation; C, Dex-CRH plasma ACTH obtained 30 min after CRH stimulation; ●, CD; ○, healthy volunteers.

The observation that the lowest plasma dexamethasone levels in the study were found in the two normal volunteers, whose Dex-CRH-stimulated plasma cortisol increased above 38 nmol/L at 45 min, suggests that dexamethasone levels may aid interpretation of the Dex-CRH test. As with other tests that use dexamethasone, the Dex-CRH test should be interpreted with caution in patients receiving medications that affect dexamethasone metabolism.

We conclude that plasma cortisol measurements obtained during the Dex-CRH test are suppressed in normal volunteers below those found in CD. Although its value in patients with episodic hormonogenesis has not been demonstrated, the Dex-CRH test may be useful in evaluating patients with features of CS and little, or no, hypercortisoluria.

Acknowledgments

We thank the nurses of the 10-West Endocrinology inpatient ward and the 9th floor outpatient clinic at the National Institutes of Health, Barbara Filmore, and Shawnia Forrester for helping to carry out this study.

References

- Liddle G. 1960 Tests of pituitary-adrenal suppressibility in the diagnosis of Cushing's syndrome. *J Clin Endocrinol Metab.* 20:1539-1561.
- Eddy R, Jones A, Gilliland PF, et al. 1973 Cushing's syndrome: a prospective study of diagnostic methods. *Am J Med.* 55:621-630.
- Schteingart D. 1989 Cushing's syndrome. *Endocrinol Metab Clin North Am.* 18:311-338.
- Crapo LM. 1979 Cushing's syndrome: a review of diagnostic tests. *Metabolism.* 28:955-977.
- Yanovski JA, Cutler Jr GB, Chrousos GP, Nieman LK. 1993 Corticotropin-releasing hormone stimulation following low-dose dexamethasone administration: a new test to distinguish Cushing's syndrome from pseudo-Cushing's states. *J Am Med Assoc.* 269:2232-2238.
- Nieman LK, Chrousos GP, Oldfield EH, Avgerinos PC, Cutler Jr G, Loriaux DL. 1986 The ovine corticotropin-releasing hormone stimulation test and the dexamethasone suppression test in the differential diagnosis of Cushing's syndrome. *Ann Intern Med.* 105:862-867.
- Gold PW, Loriaux DL, Roy A, et al. 1986 Physiology of hypercortisolism in depression and Cushing's disease. *N Engl J Med.* 314:1329-1335.
- Grossman A, Howlett T, Perry L, et al. 1988 CRF in the differential diagnosis of Cushing's syndrome: a comparison with the dexamethasone suppression test. *Clin Endocrinol (Oxf).* 29:167-178.
- Rupprecht R, Lesch K, Muller U, et al. 1989 Blunted adrenocorticotropin but normal β -endorphin release after human corticotropin-releasing hormone administration in depression. *J Clin Endocrinol Metab.* 69:600-603.
- Bernini GP, Argenio GF, Cerri F, Franchi F. 1994 Comparison between the suppressive effects of dexamethasone and loperamide on cortisol and ACTH secretion in some pathological conditions. *J Endocrinol Invest.* 17:799-804.
- Yanovski JA. 1995 The dexamethasone-suppressed CRH test in the differential diagnosis of Cushing disease and pseudo-Cushing states. *The Endocrinologist.* 5:169-175.
- Avgerinos PC, Yanovski JA, Oldfield EH, Nieman LK, Cutler Jr G. 1994 The metyrapone and dexamethasone suppression tests for the differential diagnosis of the adrenocorticotropin-dependent Cushing syndrome: a comparison. *Ann Intern Med.* 121:318-327.
- Flack MR, Oldfield EH, Cutler Jr GB, et al. 1992 Urine free cortisol in the high-dose dexamethasone suppression test for the differential diagnosis of the Cushing syndrome. *Ann Intern Med.* 116:211-217.
- Nieman LK, Oldfield EH, Wesley R, Chrousos GP, Loriaux DL, Cutler Jr G. 1993 A simplified morning ovine corticotropin-releasing hormone stimulation test for the differential diagnosis of adrenocorticotropin-dependent Cushing's syndrome. *J Clin Endocrinol Metab.* 77:1308-1312.
- Findling JW, Doppman JL. Biochemical and radiologic diagnosis of Cushing syndrome. *Endocrinol Metab Clin North Am.* 23:511-537.
- Swets JA. 1988 Measuring the accuracy of diagnostic systems. *Science.* 240:1285-1293.
- Beck JR, Shultz EK. 1986 The use of relative operating characteristic (ROC) curves in test performance evaluation. *Arch Pathol Lab Med.* 110:13-20.
- Dickek HL, Nieman LK, Oldfield EH, Pass HI, Malley JD, Cutler Jr G. 1994 A comparison of the standard high dose dexamethasone suppression test and the overnight 8-mg dexamethasone suppression test for the differential diagnosis of adrenocorticotropin-dependent Cushing's syndrome. *J Clin Endocrinol Metab.* 78:418-422.
- Caro JF, Meikle AW, Check JH, Cohen SN. 1978 "Normal Suppression" to dexamethasone in Cushing's disease: an expression of decreased metabolic clearance for dexamethasone. *J Clin Endocrinol Metab.* 47:667-670.
- Kapcala LP, Hamilton SM, Meikle AW. 1984 Cushing's disease with 'normal suppression' due to decreased dexamethasone clearance. *Arch Intern Med.* 144:636-637.
- Brown RD, Van Loon GR, Orth DN, Liddle GW. 1973 Cushing's disease with periodic hormonogenesis: one explanation for paradoxical response to dexamethasone. *J Clin Endocrinol Metab.* 36:445-451.
- Yasuda K. 1996 Cyclic Cushing's disease: pitfalls in the diagnosis and problems with the pathogenesis. *Intern Med.* 35:169-170.
- Hermus AR, Pieters GF, Borm GF, et al. 1993 Unpredictable hypersecretion of cortisol in Cushing's disease: detection by daily salivary cortisol measurements. *Acta Endocrinol (Copenh).* 128:428-432.
- Stewart PM, Venn P, Heath DA, Holder G. 1992 Cyclical Cushing's syndrome. *Br J Hosp Med.* 48:186-187.
- Shapiro MS, Shenkman L. 1991 Variable hormonogenesis in Cushing's syndrome. *Q J Med.* 79:351-363.