Techniques used for assessing the sense of smell

Assessment of the sense of smell is a challenging clinical investigation. Although a wide range of tests are available, many are modifications of tests designed more than 20 years ago. This article describes the smell tests that are available, and consider smell assessment after nasal surgery.

The ability to smell is often not appreciated but loss of smell can result in a significant disability. Objective assessments for vision, hearing and sensation are well established in normal medical practice, but smell tests are largely restricted to specialists with an interest in smell disorders.

The perception of smell is complex and relies on the many receptors in the nasal mucosa as well as multiple connections throughout the brain. Devising a smell test that accurately assesses the complete perception of smell has proven to be a challenge.

Accurate assessment of the sense of smell is important in patients presenting specifically with smell disorders or loss of smell, but also after head trauma. Fortunately, the loss of the sense of smell after sinus or nasal surgery is unusual, but this can occur after sinus surgery, septal surgery and rhinoplasty (Briner et al, 2003). However, if it does occur, the disability can be severe and a compensation claim may follow. A formal assessment of the sense of smell before and after surgery may therefore provide important information.

There are now several commercially available techniques for assessing the sense of smell, each providing a numeric score of the subject's ability to smell. These tests have all undergone validation and generally offer a reliable assessment of the sense of smell, but there are limitations that need to be appreciated in interpreting the results.

Basically, smell tests can be best described as follows (*Table 1*):

1. Threshold tests – the lowest concentration of odorant that can be detected
2. Identification tests – the ability to identify a suprathreshold odour
3. Discrimination tests – evaluation of the ability to differentiate odours.

Before the development of these commercial tests, clinical assessment of the ability to smell was reliant on using bottles with specific odorant solutions such as oil of cloves, camphor, eucalyptus oil, peppermint, asfoetida and one bottle containing ammonia to catch out malingerers.

Table 1. Categories of individual smell tests

Qualitative	Zurich
	Pocket Smell Test
	Quick Smell Identification Test
	Connecticut Chemosensory Clinical Research Center
	Sniffin' Sticks
Quantitative	Cross-Cultural Smell Identification Test
Qualitative and quantitative	University of Pennsylvania Smell Identification Test
	Sniff Magnitude Test

Current methods of smell assessment

University of Pennsylvania Smell Identification Test

The University of Pennsylvania Smell Identification Test (UPSIT; Sensonics Inc., Haddon Heights, NJ; *Figure 1*) was the first olfactory test to have supra-threshold odourants in microencapsulated crystals impregnated

Figure 1. The University of Pennsylvania Smell Identification Test (UPSIT) scratch and sniff test.

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into test booklets that are released by scratching – the scratch and sniff technique (Doty et al, 1984). There are four booklets with a total of 40 odourants. Patients must choose one from a list of four odourant possibilities on the respective page of the booklet, irrespective of whether or not they can detect the odour.

The UPSIT is validated, easy to perform, and alerts the clinician to olfactory malingerers. The test is sensitive to age and gender, and provides an estimate of the percentile of the patient's ability to smell. It is also highly reliable and reproducible (test–retest $r > 0.90$) (Doty et al, 1985).

Being the most widely used olfactory test, many subsequently developed methods of testing have used the UPSIT or its modifications as a yardstick with which to validate their results (Frank et al, 2004).

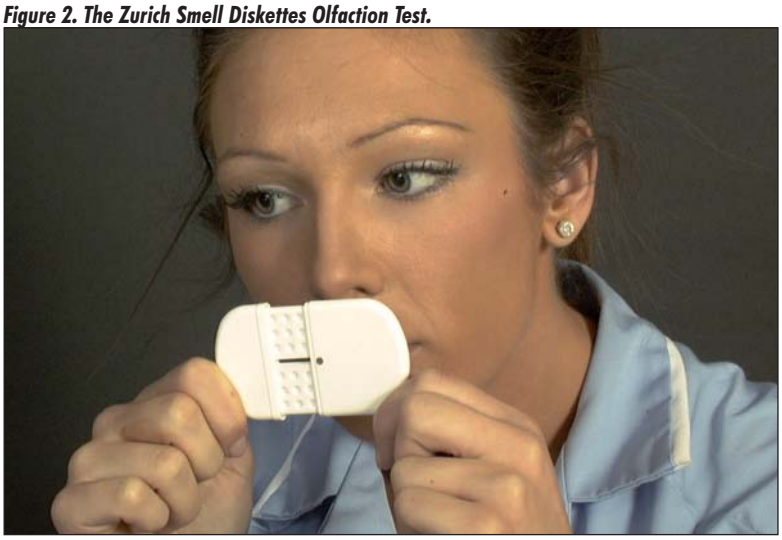
Cross-Cultural Smell Identification Test

Despite being available in four languages (English, Spanish, French and German), problems are faced when the UPSIT is applied to different cultures unfamiliar with some of the odours used, giving an inaccurate assessment of olfactory function (Hashimoto et al, 2004). For example, UK patients are not aware of the smell of items such as pumpkin pie and root beer. Currently, the UPSIT is being modified for use by UK patients by replacing unfamiliar items with those that are more commonly appreciated.

The UPSIT analysis is also time consuming in a busy clinical setting, taking between 10–15 minutes for patients to identify the 40 odours.

Doty et al (1996) therefore developed the Cross-Cultural Smell Identification Test (CC-SIT; Sensonics Inc., Haddon Heights, NJ). This is a short 12-odourant forced-choice test based on items from the UPSIT but which takes account of culture. The CC-SIT has a relatively lower reliability ($r = 0.71$), but this is proportionate to the reduction in the number of test odours. CC-SIT is also unable to differentiate between anosmic and malingering patients with low scores, but given the short time it can be applied in (less than 5 minutes), it is still a reliable test for clinical purposes.

Figure 2. The Zurich Smell Diskettes Olfaction Test.



Other modifications of UPSIT

Another modified version of the UPSIT is the Pocket Smell Test (PST; Sensonics Inc., Haddon Heights, NJ). Even though the PST does not have any validity or reliability studies, the three-odour forced-choice test only has a small chance (1 in 64) of missing true total anosmia, and is particularly useful in screening for anosmia in patients with Alzheimer's disease (Duff et al, 2002). Incorrectly identifying one odour indicates impaired olfactory function.

The Quick Smell Identification Test (Q-SIT; Sensonics Inc., Haddon Heights, NJ) is a very similar adaptation of the UPSIT to the PST, but it does not have a full forced-choice format: patients are given the option of indicating if a smell is not perceived or it does not correspond to any of the four choices. The Q-SIT test–retest reliability is quoted as r=0.87: this high value may be in part the result of the repeat tests being performed on the same day (Jackman and Doty, 2005).

A three-odour test based on a modified UPSIT has been reported to be successful in screening for anosmia in patients with traumatic brain injury (Callahan and Hinkebein, 2002).

The Zurich test

The Zurich test, or the Smell Diskettes Olfaction Test (Novimed Medizintechnik, Dietikon, Switzerland), is a simple 8-item odour-identification test (Briner and Simmen, 1999; *Figure 2*). Odours are presented from reusable smell diskettes that can be used for up to 6 months. Patients are asked to try and identify odours from a triple-forced multiple choice test. The score ranges from 0–8: a normosmic patient should score 7 or 8; a score of 6 or less would indicate hyposmia, anosmia or malingering. While being a reliable screening test, patients who score 6 or less ideally require further tests to assess the degree of olfactory impairment. The odours presented are well in excess of normal threshold and this can induce apparent conflict in results if compared to the UPSIT analysis score.

Connecticut Chemosensory Clinical Research Center

In the Connecticut Chemosensory Clinical Research Center (CCCRC), the odour threshold is assessed by using squeeze bottles of butanol at different concentrations.

Odour identification is assessed by presenting eight different odourants in glass sniff-bottles that have to be identified from a list of sixteen odours (Cain et al, 1988).

Comparison between the CCCRC and the UPSIT tests show a high level of agreement ($r = 0.92$), but

the correlation was highest for the odour identification component compared to the threshold component and the odour identification component was also a more sensitive means of smell assessment (Cain and Rabin, 1989).

'Sniffin' Sticks'

The Sniffin' Sticks test battery (Burghart, Wedel, Germany) was developed in Germany in the mid-1990s at a time when there were no olfactory tests designed specifically for the European region (Kobal et al, 1996). The test has three parts: odour threshold level by presenting increasing concentrations of butanol; odour discrimination; and smell identification. The three sections are performed in order of threshold, discrimination and identification and the scores are then summed. This form of the Sniffin' Sticks test is known as the Sniffin' Sticks Extended Test.

The odour-dispensing device for this test is based on a design similar to felt-tip pens with the objective of releasing a constant concentration of odorants at any one time. The device is filled with a liquid odorant or an odorants dissolved in propylene glycol.

The test is fully validated and reproducible (test–retest $r = 0.72$) but it is time-consuming and takes up to 30 minutes to complete. Normative data for the Sniffin' Sticks test are based on a multicentre investigation of more than 1000 subjects (Kobal et al, 2000). Anosmia is likely if butanol is not detected in the threshold test and the total summated score is 15 or less. Hyposmia is indicated by positive detection of butanol but a total score of 30 or less.

A 16-odour screening test (Sniffin' Sticks Screening Test) is now available which is a quick, reliable (test–retest $r = 0.77$) smell identification test that differentiates between normosmia, hyposmia and anosmia (Hummel et al, 2001). A similar 12-item identification test for lateralized olfactory testing is reported to be useful in patients with unilateral anosmia.

The shelf-life of an appropriately used Sniffin' Stick is about 1 year and the screening test therefore has a good cost–benefit ratio.

Sniff Magnitude Test

A relatively recent advancement is the Sniff Magnitude Test (SMT; Compusniff, LLC. Cincinnati, Ohio) (Frank et al, 2002). The SMT is based on the principle that people sniff less when an unpleasant odour is presented to them: the reduction in sniffing is measured by a pressure-sensitive piezoelectric transducer attached to bilateral nasal cannulae (*Figure 3*). This SMT is highly reliable (test–retest reliability $r = 0.80$) and is reported as being very effective for evaluating olfaction in children, people with cognitive impairment or those who do not speak English (Frank et al, 2004). The SMT device does, however, require dedicated computational facilities to be available in the clinic.

Electro-olfactometry

Electro-olfactograms (EOG) are electrical potentials of the olfactory epithelium that occur in response to electrical stimulation (Knecht and Hummel, 2004). The EOG represents the sum of generated potentials of olfactory receptor neurones. Its use has been limited to animal studies, although some reports suggest it may be of use in diagnosing anosmia caused by disorders of the olfactory epithelium or disorders of the central olfactory tract. Among other results, EOGs have been used to provide evidence for the dominant role of the CNS in olfactory desensitization, for the functional characterization of the olfactory epithelium, the specific topographical distribution of olfactory receptors, or the expression of olfactory receptor neurons in response to exposure to odorants, and the characterization of certain odorants as olfactory receptor antagonists (Furukawa et al, 1989).

Conclusions

Smell tests are essentially subjective and rely on the integrity of the patient's responses. There are now several commercially available methods for assessing the sense of smell, each having its own advantages and disadvantages. These tests generally provide reliable information about the patient's ability to smell and are extremely helpful when assessing smell disorders.

Although surgery on the nose or sinuses may have a profound effect on a patient's ability to smell, these events are fortunately rare. However, the potential for complaints exists and an awareness of this possibility should be maintained. A formal assessment of the sense of smell before sinonasal surgery should therefore always be considered. **BJHM**

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Briner HR, Simmen D (1999) Smell Diskettes as screening test of olfaction. *Rhinology* **37:** 145–8

Briner HR, Simmen D, Jones N (2003) Impaired sense of smell in patients with nasal surgery. *Clin Otolaryngol* **28:** 417–19

Cain WS, Rabin MD (1989) Comparability of two tests of olfactory functioning. *Chem Senses* **14:** 479–85

Cain WS, Gent JF, Goodspeed RB, Leonard G (1988) Evaluation of olfactory dysfunction in the Connecticut Chemosensory Clinical Research Center. *Laryngoscope* **98:** 83–8

Callahan CD, Hinkebein JH (2002) Assessment of anosmia after traumatic brain injury: performance characteristics of the University of Pennsylvania Smell Identification Test. *J Head Trauma Rehabil* **17:** 251–6

KEY POINTS

- Olfactory tests are categorized into threshold, identification and discriminatory types.
- Olfactory assessment is challenging and different tests are available depending on whether quantitative or qualitative results are to be obtained.
- Olfactory testing shows poor reliability when applied across different populations.
- Assessment of smell should always be considered in patients undergoing sinonasal surgery.

Doty RL, Shaman P, Dann M (1984) Development of the University of Pennsylvania Smell Identification Test: A standardized microencapsulated test of olfactory function. *Physiol Behav* **32:** 489–302

Doty RL, Newhouse MG, Azzalina JD (1985) Internal consistency and short-term test-retest reliability of the University of Pennsylvania Smell Identification Test. *Chem Senses* **10:** 297–300

Doty RL, Marcus A, Lee WW (1996) Development of the 12-item Cross-Cultural Smell Identification Test (CC-SIT). *Laryngoscope* **106:** 353–6

Duff K, McCaffrey RJ, Solomon GS (2002) The Pocket Smell Test: successfully discriminating probable Alzheimer's dementia from vascular dementia and major depression. *J Neuropsychiatry Clin Neurosci* **14:** 197–201

Frank RA, Dulay MF, Gesteland RC (2002) Assessment of the Sniff Magnitude Test as a clinical test of olfactory function. *Physiol Behav* **78:** 195–204

Frank RA, Dulay MF, Niergarth KA, Gesteland RC (2004) A comparison of the sniff magnitude test and the University of Pennsylvania Smell Identification Test in children and nonnative English speakers. *Physiol Behav* **81:** 475–80

Furukawa M, Kamide M, Ohkado T et al (1989) Electro-olfactogram (EOG) in olfactometry. *Auris Nasus Larynx* **16**(1): 33–8

Hashimoto Y, Fukazawa K, Fujii M et al (2004) Usefulness of the odor stick identification test for Japanese patients with olfactory dysfunction. *Chem Senses* **29:** 565–71

Hummel T, Konnerth CG, Rosenheim K, Kobal G (2001) Screening of olfactory function with a four-minute odor identification test: reliability, normative data, and investigations in patients with olfactory loss. *Ann Otol Rhinol Laryngol* **110:** 976–81

Jackman AH, Doty RL (2005) Utility of a three-item smell identification test in detecting olfactory dysfunction. *Laryngoscope* **115:** 2209–12

Kobal G, Hummel T, Sekinger B et al (1996) "Sniffin' sticks": screening of olfactory performance. *Rhinology* **34:** 222–6

Kobal G, Klimek L, Wolfensberger M et al (2000) Multicenter investigation of 1,036 subjects using a standardized method for the assessment of olfactory function combining tests of odor identification, odor discrimination, and olfactory thresholds. *Eur Arch Otorhinolaryngol* **257:** 205–11

Knecht M, Hummel T (2004) Recording of the human electro-olfactogram. *Physiol Behav* **83**(1): 13–19